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Response of Tef (Eragrostis tef (Zucc.) Trotter) to Phosphorus Fertilizer Rates in Ezha and Goro District of Central Ethiopia

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Abstract
Tef (Eragrostis tef (Zucc.) Trotter) is the principal Ethiopian small grain cereal. Poor soil fertility management limits the production and productivity of tef. This study was designed to determine the optimum level of phosphorous (P) for better tef performance. The field experiment was conducted Ezha in Guraghe and Goro in South West Shewa in 2020/21. Seven levels of phosphorus (0, 23, 34.5, 46, 57.5, 69 and 80.5kg/ha) were arranged in randomized complete block design (RCBD) with three replications. Quncho, a commonly cultivated tef variety was used in the experiment. Analysis of the data revealed significantly ($P < 0.05$) higher grain yield (2074.5 and 2149.3 kg ha^{-1}) from the treatments of 69 and 80.5 P, respectively; while, significantly ($p < 0.05$) lower grain yield (629.5 kg ha^{-1}) was obtained from nil. To evaluate the feasibility of treatments with view of farmers' practices, a partial budget analysis was conducted on grain yield of tef and consequently the highest marginal rate of return were obtained from fertilization of 69 and 80.5 P.. Therefore, based on the data obtained from the experiment, application of 69 P was recommended as management options for the production of high tef potential area of Ezha in Gurage and Goro in South West Shewa, Central Ethiopia.
Keywords: Tef, Phosphorus, Response and Fertilizer
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INTRODUCTION

Tef (*Eragrostis tef (Zucc.) Trotter)* is the Ethiopian main crop which is used for human food, cash and animal feed. Because of its gluten free properties, tef become a popular health food all over the world. Ethiopia is the home of tef, a patented and a center of diversity (Vavilov, 1951). It is grown by more than 6.8 million households (CSA, 2018). Taking up over 2.6 million hectares (23%) of the grain crop area, which is larger than any of the six primary cereals (CSA, 2018). Its main characteristics include the resilience to drought and waterlogging problems, as well as its use as a low-risk crop to replace long-maturing crops; like maize and sorghum (Assefa et al., 2015). It may be grown from sea level to 2,800 meters above sea level, with a variety of rainfall, temperature and soil conditions (Seyfu, 1997).

Tef has gained international anticipated among cash crops as a result of its nutritional and health-related properties, and it has been attracting an export market. Tef grain contains a large amount of fiber, minerals, and vitamins as well as all eight essential amino acids (**Sharifiet al., 2017)**. It's commonly used in the preparation of *'injera,'* a popular pancake-like bread (Seyfu, 1997). It also has a high crude protein content, a fast growth rate, and the ability to be collected for pasture numerous times. Due to the lack of gluten in its grain, which is a cause of celiac disease (Seyfu, 1997, and Fikadu et al., 2019).

Tef is the most extensively grown cereal crop in the country, covering 2,866,052.99 ha and yielding 1.7 t ha_{-1} on average (CSA, 2018). Oromia, Amhara and the Southern Nations Nationalities and Peoples are Ethiopia's leading tef producers (SNNP). Tef accounted for 22, 32, and 29 percent of total area planted in each state, with yields of 1.2, 1.6, 1.2, and 1.3 t ha_{-1}; tef ranks first among cultivated food crops, with a projected production area of 2730272.95 ha and a mean yield of 1.38 t ha_{-1} (CSA, 2018). Since a few years, tef research has been performed in the region, and some promising varieties have been adapted and under production. Despite this, due to a number of soil-plant-management-related issues, it has proven unable to boost its yield. Low soil fertility and poor nutrient management appear to be two main determinants for its yield gap. Farmers' use of suboptimal quantities of mineral fertilizers, continuous cropping, and high proportions of cereals in the cropping system intensify the condition in the area. Continuous removal of biomass (grain and crop residues) from cropland without proper nutrient replacement can deplete soil nutrient reserves quickly, endangering agricultural production's long-term viability (Desalegn et al., 2020).

Inorganic fertilizers are important inputs in every agricultural production system because they provide vital nutrients in a manner that is readily available to plants. On light soils like Nitosols, Luvisols, and Cambisols, fertilizer rates of 25-40 kg N and 10-20 kilogram P ha_{-1} are advised; however, on heavy soils like Vertisols, fertilizer rates of 50-60 kg N and 30-35 kg P per hectare are recommended (Vanlauwe et al., 2002). Attempts to determine the proper fertilizer rates and other agronomic requirements for tef in the area have so far been unsuccessful. Nitrogen and phosphorus are the most significant nutrients among the key yield-limiting plant nutrients because the crop requires high levels of both. However, research data on phosphorus fertilizer application rates is scarce in this area. As a result, efforts must be made to improve tef production by using the appropriate amount of P fertilizers.

MATERIALS AND METHOD

The experiment was conducted at on-station of Wolkite Agricultural Research Center (WkARC) during 2020/21 cropping season in Ezha and Farmer Training Center (FTC) in Goro in in Central Ethiopia.

Table 1. Background information of testing sites

Parameters	Wolkite ARC-on-station	Goro FTC
Soil type	*Abolse*	Vertisol
Altitude (masl)	1960	1815
Soil Color	*Bore*	Black soil

Where; masl=meter above sea level

The treatments include seven level of phosphorus (0, 23, 34.5, 46, 57.5, 69 and 80.5kg/ha) were arranged in randomized complete block design (RCBD) with three replications; and Quncho, a commonly cultivated tef variety in the experiment sites, was used in the experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and plot size of 4m x 4m (16 m^2) and net harvestable plot size 14.44 m^2, spaced 0.2m between rows, 1m between plots and blocks. Urea was applied 100 kg/ha for all treatments at both locations with split application. The first phase at early two weeks later after germination at knee stage, whereas the second phase applied near to heading of the crop. All recommended agronomic management practices was applied to all treatments uniformly. Yield and growth data (plant height, panicle length, grain yield, aboveground biomass and harvest index) were collected. Analysis of variance was performed using R software.

Initial soil physicochemical properties the experimental site:- Selected physicochemical properties of surface soil of the study site were analyzed based on the analytical results of the composite soil samples collected at depth of 0-20cm from experimental site before sowing. On the basis of particle size distribution, the soil contained sand 18%, Silt 38% and clay 44 %(Table 2). According to the soil textural class determination triangle, soil of the experimental site was found to be clay. The soil reaction of the experimental site was 5.4, which is slightly weak. The CEC value of the soil sample was high (39.3 Meq/100g soil), indicating its better capacity to retain the cation. The organic carbon content of the soil was 2.28%. Organic carbon content of the soil was medium indicating moderate potential of the soil to supply nitrogen to plants through mineralization of organic matter (Tekalign et al., 2013).

Table 2. Initial soil physicochemical properties the experimental site

Parameter	Value
Texture	Clay
Clay (%)	44
Sand (%)	18
Silt (%)	38
pH	5.4
OM (%)	2.28
OC (%)	1.32
CEC(Meq/100g soil)	39.3

Where: pH=pH levels; OM=organic matter, OC=organic carbon; CEC=cation exchange capacity

RESULTS AND DISCUSSION

The influence of varying amounts of phosphorus fertilizer on all features of the tef variety was significantly different ($P<0.001$), necessitating an analysis of variance (Table 3). For the investigated localities, the use of phosphorus fertilizer variation aids in the extraction of greater tef variety mean grain yields. Plant height, panicle length, above-ground biomass, grain output, and harvest index all varied significantly ($p<0.001$). When different levels of P fertilizer were employed and published similar findings (Getahun et al., 2018 & Wakjira, 2018).

Table 3. Analysis of Variance of plant height, panicle length, above ground biomass, harvest index and yield by the influence of different rate of phosphorus

Source	DF	PLH (cm)		PL (cm)		AGBM (t/ha)		HI (%)		GY (kg/ha)	
		MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F
location	1	8242	<.0001	719	<.0001	58	<.0001	0.0029	0.524	5733531	<.0001
Replication	2	17	0.8371	7	0.6736	0.45	0.7486	0.0007	0.911	34654	0.5025
Treatment	6	1186	<.0001	154	<.0001	7.4	0.0014	0.0290	0.004	1929803	<.0001

Where; DF = Degrees of freedom, GY = Grain yield, PLH = Plant height, PL = Panicle length, AGBM = Above ground biomass, HI = Harvest index, t/ha=tone per hectare, kg/ha= kilo gram per hectare, MS= mean square, Pr= probability

Growth Parameters

Plant height: The application of phosphorous (P) fertilizer significantly ($p< 0.001$) influenced tef plant height and the mean tef plant height ranged from 77.7 to 120.5 cm (Table 4). The highest mean plant height (112.2cm, 112.4 cm and12.5cm) was recorded on 57.5%, 69 % and 80.5 % P prescribed phosphorus ha_{-1}, respectively. While the lowest mean plant height (77.7 cm) was obtained from the control treatment (Table 4). All P fertilized plots generated considerably longer plant heights than unfertilized plots. In agreement with this, previous studies on tef found that plant height risen linearly with increasing P fertilization levels that could be attributed to plant growth as P is involved in cellular metabolism (Getahun et al., 2018, Wakjira, 2018, Wakene et al., 2014 and Rashid et al., 2007).

Panicle length: Significantly ($p < 0.05$) longer panicle length of 42.4, 42.2, 41.5, 41.4 and 41.3 cm was recorded from relatively higher phosphorous levels of 80.5, 34.5, 57.5, 46 and 69 kg ha_{-1}. Whilst; panicle length of 28.3 and 36 cm was recorded from control and relatively lower phosphorous level of 23 kg ha_{-1} (Table 4). The use of P fertilizer had a substantial effect on panicle length (Getahun et al., 2018). Previous studies also asserted a longer panicle length due to an increased use of phosphorous fertilizer levels (Getahun et al., 2018). Furthermore, balanced fertilization application and efficient nutrient utilization results to high photosynthetic productivity and dry matter accretion, which leads to increased panicle length (**Feyera et al., 2014)**. It's possible that the increase in plant height with rising P rate is due to sufficient P uptake by plants, which stimulates plant growth. In addition to its structural role, phosphorus is the most important element in energy transfer for cellular metabolism. Application of balanced fertilizer and efficient nutrient use leads to high photosynthetic productivity and formation of high dry above ground biomass (Asefa et al., 2014)

Yield and yield component

Aboveground biomass: Above ground harvested biomass of tef was significantly (p<001) influenced by Phosphorous fertilizer rate (Table 3). Significantly higher above ground biomass yield of 5.5 and 5.7 ton/ha was obtained from the highest phosphorous fertilizer levels of 57.5 and 69 kg ha_{-1}; while, the lower above ground biomass yield of 3.4, 3.9 and 3.3 $tonha_{-1}$ was recorded from control and lower phosphorous fertilizer levels of 0, 23 & 34.5 $kgha_{-1}$ (Table 4).

Grain yield: The application of different phosphorous fertilizer rates significantly ($p < 0.001$) influenced tef grain yield (Table 3). Application of P fertilizer rates of 80.5 and 69 $kgha_{-1}$ generated significantly ($p < 0.001$) tef grain yields of 2149.3 and 2074.5 kg ha_{-1} (Table 3 and 4). Contrarily control plots produced significantly ($p < 0.001$) lower tef grain yield of 629.5 kg ha_{-1} (Table 4 and Fig. 1). Similar result of increasing tef grain yield with increased phosphorous fertilizer rates was reported in previous studies (Getahun et al., 2018, and Wakjira, 2018).

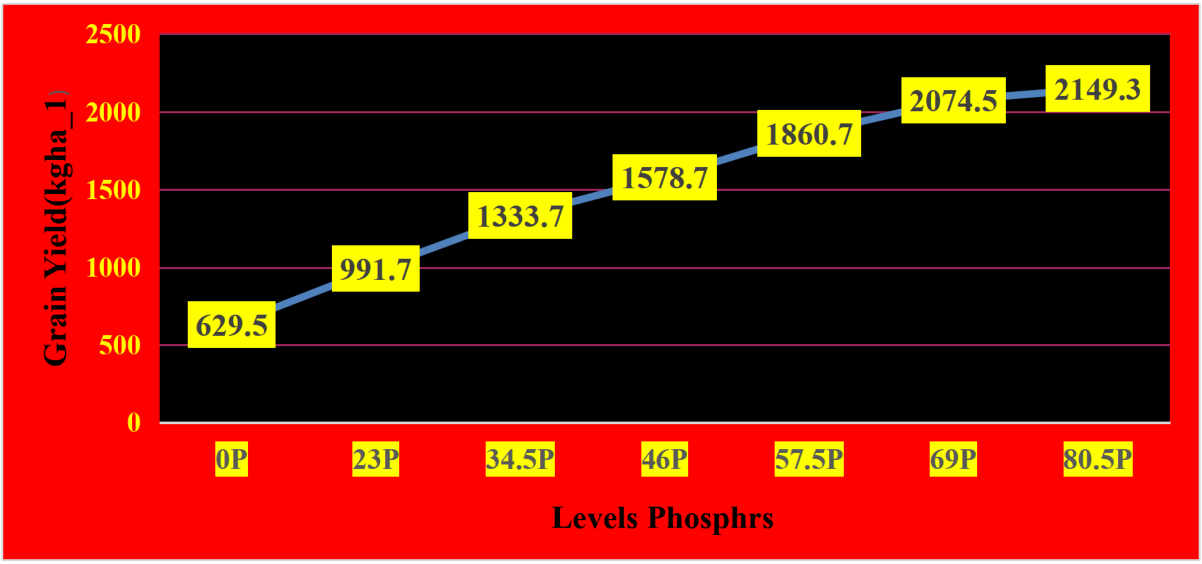

Figure 1. Tef grain yield in response to different rates of phosphorus fertilizer

Harvest Index:-The analysis of variance revealed a significant ($p<0.001$) difference in the ratio of grain yield to above ground biomass yield among the different levels (Table 3). The maximum harvest index (35 to 42 percent) was recorded from phosphorus fertilizer rates of 34.5, 46, 57.5, 69 and 80.5 kgha$_{-1}$, while the lowest harvest index (22 percent) was recorded from the control (Table 4). In line with this finding, previous studies asserted increasing P fertilizer rate boosts the harvesting index (Wakjira, 2018; and Gebrekidan & Seyoum, 2006).

Table 4.Mean value of growth, yield and related traits

P fertilizer rates (kg/ha)	PLH(cm)	PL(cm)	AGBM(tha^{-1})	HI (%)	GY(Kgha^{-1})
0	77.7^{c}	28.3^{b}	3.4^{c}	0.22^{c}	629.5^{e}
23	105.3^{b}	36.0^{b}	3.9^{bc}	0.28^{bc}	991.7^{d}
34.5	112.0^{ab}	42.2^{a}	3.3^{c}	0.42^{a}	1333.7^{c}
46	112.2^{ab}	41.4^{a}	5.2^{ab}	0.33^{ab}	1578.7^{c}
57.5	115.2^{ab}	41.5^{a}	5.5^{a}	0.35^{ab}	1860.7^{b}
69	112. 4^{ab}	41.3^{a}	5.7^{a}	0.36^{ab}	2074.5^{ab}
80.5	120.5^{a}	42.4^{a}	5.7^{a}	0.40^{a}	2149.3^{a}
Mean	**107.906**	**39.718**	**4.669**	**0.336**	**1516.857**
LSD	**11.566**	**4.849**	**1.462**	**0.099**	**261.07**
CV (%)	**9.115**	**10.380**	**26.630**	**24.947**	**14.635**
R-Square	**0.832**	**0.753**	**0.676**	**0.443**	**0.917**

Where; PLH= plant height, PL= panicle length, AGBM=above ground biomass, HI= harvest index, cm= centimeter, t/ha=tone per hectare, GY=grain yield and kg/ha= kilo gram per hectare

Economic Analysis

The biggest gross farm gate advantage (78501.3) was obtained from the effect of 80.5 P fertilizer, while the second gross benefit (75738.8 ETB ha-1) was obtained from the effect of 69 P fertilizer (Table 5). As a result, rather than focusing exclusively on the largest grain yield, it's critical to compare treatments in order to rule out undesirable treatments based on economic profitability, because the highest grain yield may not be appealing if it comes at a high cost. As a result, the plot treated with 69 P had the second highest net benefit, with 75738.8 ETB ha-1. Every birr invested in tef production would rise by 3743 percent if this procedure was applied (Table 5). As a result, the 69 P influence was more cost-effective than any other treatment (Table 5).The application of 69 P resulted in the greatest increase in mean grain output when compared to the other treatments. It provides the best return on investment for the money invested; it increased profit and output; while, reducing costs (Table 5). With a positive marginal rate of return, the overall effect of the phosphorus fertilizer rate was economically viable

Table 5.Partial budget analysis

Trt #	Treatment	Grain Yield (Kg/ha)	Adjusted Yield (Kg/ha)	Gross Benefit (birr)	Cost of Urea (ETB/ha)	Cost of P (ETB/ha)	Labor cost	TVC	Net Benefit (ETB/ha)	MRR (%)
T1	0P	630	62.95	196719	1650	0	12600	17375	17934.4	1032
T2	23P	992	99.17	309906	1650	850	12600	18225	29168.1	1600
T3	34.5P	1334	133.37	416781	1650	1275	12600	18650	39813.1	2135
T4	46P	1579	157.87	493344	1650	1700	12600	19075	47426.9	2486
T5	57.5P	1861	186.07	581469	1650	2125	12600	19500	56196.9	2882
T6	69P	2075	207.45	777938	1650	2550	12600	20550	75738.8	3686
T7	80.5P	2149	214.93	805988	1650	2975	12600	20975	78501.3	3743

Where; Trt #=treatment number, T= treatment, kg/ha= kilo gram per hectare, ETB/ha= Ethiopian birr per hectare, TVC= Total variable cost, MRR= marginal rate of return

CONCLUSION

In the tef crop, higher rates of P fertilizer application had a significant impact on vegetative metrics including panicle length and plant height. The application of higher P fertilizer rates resulted in a significant increase in biomass and grain yield. With 69 % P fertilizer kgha-1 and 80.5% P fertilizer kgha-1, the greatest marginal rate of return was attained. As a result, it can be stated that applying 69 percent P $kgha_{-1}$ fertilizers to high-potential areas of Ezha in Gurage and Goro in South West Shewa at Central Ethiopia is more worthwhile for farmers in terms of tef production.

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