Sustainability in Environment
ISSN 2470-637X (Print) ISSN 2470-6388 (Online)
Vol. 9, No. 2, 2024
www.scholink.org/ojs/index.php/se

Original Paper

Determination of NPS Fertilizer rate the Yield and Yield Components of Teff [Eragrostis tef (Zucc.) Trotter] in Kuyu District North Shewa Zone, Oromia, Ethiopia

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Received: January 13, 2024 Accepted: March 07, 2024 Online Published: March 20, 2024
doi:10.22158/se.v9n2p1 URL: http://dx.doi.org/10.22158/se.v9n2p1

Abstract

Tef is the main staple food of Ethiopia. It ranks first among cereals in the country in area coverage and second in production volume; however, its productivity is almost stagnant. The Degim Tef variety was sown during the main cropping season of 2020 and 2021 in the kuyu District, Northern Oromia, and Ethiopia. The objective of this study was to determine the NPS fertilizer rate relative the determined P-critical and P-requirement factors for tef and to estimate the economically feasible NPS fertilizer rate for higher yield of tef in kuyu District. Accordingly, statically analysis of variance showed that plant height, panicle length, biomass, and grain yield were significantly ($P<0.05$) influenced by NPS fertilizer rate with N fertilizer. The highest plant height (83.59 cm), of tef was recorded from the application of 75% P-critical from NPS fertilizer rate with recommended nitrogen panicle length (29.05cm), biomass yield (7509 kg ha^{-1}) and grain yield (1635 kg ha^{-1}) of tef were recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field unfertilized which was significantly inferior to all other treatments. Furthermore, the economic analysis showed that the application of NPS fertilizer at the rate of 100% P-critical from NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial for the district. Moreover, farmers and other end users could be advised to use 100% PC from NPS fertilizer rate with recommended nitrogen for tef production in the district and other areas having similar soil type and agro- ecology.

Keywords

NPS fertilizer rate, Nitrogen fertilizer, Tef, yield

1. Introduction

In Ethiopia, Tef occupies about 3.01 million hectares (27% of the cereal crop area) of land which is more than any other major cereals such as maize (22.7%), sorghum (19%) and wheat (16%) (CSA), 2013). Ethiopian farmers prefer tef, because the grain and straw bring good prices. Its production area is increasing at an unprecedented scale due to increased market demand both in the local and foreign market. Tef is used in Ethiopia to produce the nation's staple dish enjera. Grinding tef grains into flour and mixing with water results in a spongy type of pancake.

Tef is also used to brew local beer. It has high protein, fiber, and complex carbohydrate content, relatively low calorie content, and is gluten free (Berhane *et al.,* 2011; ATA, 2013c). It accounts for between 11 and 15 percent of all calories consumed in Ethiopia (Berhane *et al*., 2011, ATA, 2013c) and provides about 66 percent of daily protein intake (Fufa *et al.,* 2011). Almost two - thirds of the Ethiopian population use tef as their daily staple food. It is estimated that per capita consumption grew by 4 percent over the last 5 years (ATA, 2013c). Tef is considered an economically superior, good, relatively more consumed by urban and richer consumers (Berhane *et al.*, 2011; Minten *et al.*, 2013). In urban areas, the share of per capita of consumption in total food expenditure is 23 percent, while in rural area this is only 6 percent. In rural areas tef is considered a luxurious grain consumed only by elders or during special occasions. Growth in average income and faster urbanization in Ethiopia are likely to increase the demand for tef over time (Berhane *et al*., 2011). Even though Ethiopia is a center of origin and diversity of tef and has the above-mentioned importance and coverage of large areas, its productivity is very low to feed the demand of its people and market.

These are due to low soil fertility and suboptimal use of mineral fertilizers in addition to weeds, lack of high yielding cultivars, erratic rainfall distribution in lower altitudes, lodging, water logging, low moisture, and low soil fertility conditions (Fufa, 1998). On the other hand, under conditions where most growth requirements are available and in organic matter rich soils, application of fertilizers without knowing its fertility status causes yield and fertilizer loss (Tekalign *et al.*, 2001).

There are different blanket fertilizer recommendations for various soil types of Ethiopia for tef cultivation. This is due to its cultivation in different agro ecological zones and soil types, having different fertility status and nutrient content

Thus, 100 kg DAP ha^{-1} and 100 kg urea ha^{-1} were set by the Ministry of Agriculture and Rural Development later (Kenea *et al.,* 2001).

Those blanket recommendations brought generally, an increase the yield of improved cultivars ranging from 1700 to 2200 kg/ha (Seyfu, 1997). Accordingly, the average national yield in the year 2010 reached 1200 kg/ha (CSA, 2010), However, the recommendations do not work for all production aspects of various soil types of different regions. Soil test-based application of plant nutrients helps to realize a higher response ratio: As the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and,

Correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization location, specific fertilizer recommendations are possible for soils of varying fertility, resource conditions of farmers and level of target yield conditions of similar soil classes and environment (Ahmed *et al.,* 2002).

Now a day's farmers are using those blended fertilizers suggested by Ethio SIS in the area where there are deficient in the soil without any recommendation of crop response to the respective fertilizers. However, the effect of NPS fertilizer rate was not determined for tef in the study area. Thus, based on the determined Pc (10 ppm) and Pf (3.03), the optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine NPS fertilizer rate in relative to determined P-critical and P-requirement factors for tef and to estimate the economically feasible NPS fertilizer rate for higher yield of tef in kuyu District.

2. Materials and Methods

2.1 Description of the Experimental Site

The study was carried out in Kuyu district, North Shewa Zone, Oromia. The district is located 42 km from the zonal capital Fiche and 156 km from Finfinne in north direction. Geographical location existed between $9^{0}35$`- $9^{o}49$'N latitude and $38^{o}03$'-$38^{o}31$'E and at an average elevation 2757 meters above sea level. The average annual rainfall ranges from 1,600-1,800 mm, while the average annual temperatures vary between 15^{o}c and 18^{o}c.

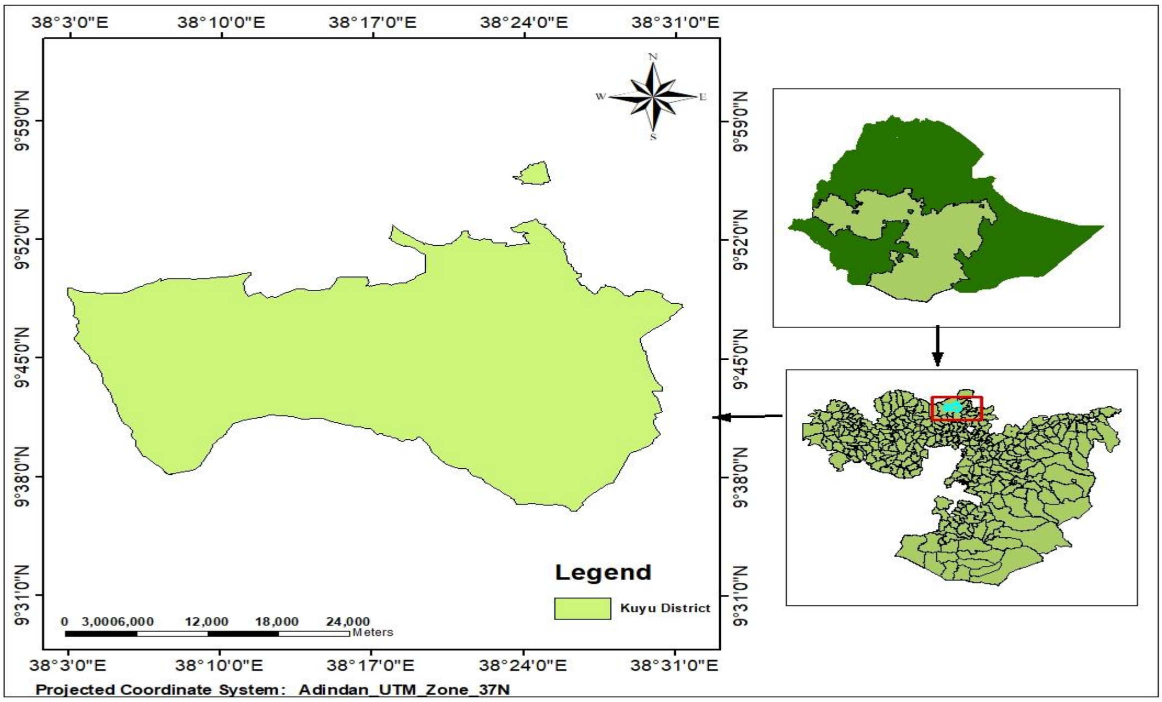

Figure 1. Map of the Study Area

2.2 Site Selection, Soil Sampling and Analysis Methods

tef production potential kebeles were selected from the district. Accordingly, 10 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, 40 surface composite soil samples were collected for two years from farmers fields for analysis at a depth of 0-20 cm in a zigzag method. The collected surface soil samples from the experimental field were air dried, grinded, and allowed to pass through a 2 mm sieve for further analysis in the laboratory (FAO, 2008). The collected soil samples were analyzed for pH (H_2O) in the suspension at a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). Organic carbon was determined by Wakley and Black procedure. Organic matter was estimated as organic carbon multiplied by 1.724. Total nitrogen was determined by the micro- Kjeldahl method and available P was determined by Olsen's method using a spectrophotometer (Olsen *et al*., 1954). Then the farmer's field was selected based on the analyzed soil sample results in which the available soil phosphorus critical phosphorus (Pc) was selected for the experiments.

2.3 Experimental Design and Treatments

The trial field study was arranged with a total of 6 treatments in a randomized complete block design (RCBD) in three replications. The recommended Nitrogen (92 kg ha^{-1}) for the district was used. The gross plot size was 3m * 3m and the space between block and plot was 70cm and 30cm, respectively. The required amount of seeds was weighed per plot by considering the recommended rate of Tef seed per hectare. Urea NPS and DAP (Di ammonium Phosphate) were used as a source of Nitrogen and Phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A Tef variety (Dagim) was used as a test crop.

The treatments were;

T1 = Control (without fertilizers).

T2 = 25% P-critical from NPS fertilizer +Recommended Nitrogen

T3 = 50% P-critical from NPS fertilizer + Recommended Nitrogen

T4 = 75% P-critical from NPS fertilizer + Recommended Nitrogen

T5 = 100% P-critical from NPS fertilizer + Recommended Nitrogen

T6 = 100% P-critical from DAP fertilizer + Recommended Nitrogen

The determined P-critical value (10 ppm) and phosphorous requirement factor (3.03) was used to calculate the rate of phosphorus fertilizer to be applied. Thus, phosphorus fertilizer rate was calculated by using the formula given below;

Rate of P-applied= (pc-pi)*pf

Where

Pc: Critical phosphorus concentration

P: Initial available P

Pf: Phosphorus requirement factor which was derived from the calibration study

Agronomic data were collected include:

Agronomic data to be collected include: plant height (cm), panicle length (cm), above ground biomass (kg ha-1) and grain yield (kg ha^{-1}),

Data Collection

Teff grain yield was harvested at the ground level from the net plot area and weighed for biomass data. Then plant height and panicle length was measured at harvest. After threshing, grain yield were cleaned and weighed. The biomass yield was determined by the addition of grain yield and straw yield for each respective treatment. Economic data such as production cost (input cost), gross income and net income, based on the current market price of the yield and input were recorded.

Data Analysis

All data recorded and collected were subjected to analysis of variance (ANOVA) using GenStat 18^{th} edition software program. The comparisons among treatment means were employed by using Least Significance Difference (LSD) at 5% significant level.

3. Results and Discussions

3.1 Selected Soil Chemical Properties of the Study Area

The results of the soil analysis indicated that the soil pH, total N, available P, and OC of the soil before planting were 5.9, 0.3%, 3.8 ppm, and 3.0%, respectively (Table 1). The soil pH of the study site was found in the range of moderately acid Tekalign (1991). According to Tekalign (1991) soils are classified depending on their total N content in percentage (%), as very high (> 0.25). Thus, the soil of the study site has high total N content. Olsen et al. (1954) classified available P content in the range < 5 as low, 5 to 10 as medium, and >10 $mg{\cdot}kg^{-1}$ as high. Thus, the soil of the study site has low P. According to Tekalign (1991), the soil organic carbon content ranges from 0.5% to 1.5%, 1.5% to 3.0 %, and > 3.0% are rated as low, medium and high, respectively. Thus, the OC content of the study area was considered as medium. According to these results, we clearly justify the need for the external application of inorganic and organic sources based on the base recommendation for the different crops grown in the area.

Table 1. Soil Status of the Experimental Site

Site	PH	OC(%)	TN(%)	Av.P (pmm)
1	5.51	3.69	0.32	5.99
2	5.51	3.99	0.34	3.31
3	5.69	3.39	0.29	4.63
4	5.55	2.49	0.21	5.74
5	5.87	1.6	0.14	4.55
6	6.36	2.69	0.23	2.37
7	6.02	3.29	0.28	2.15

8	6.31	2.39	0.21	2.66
9	6.08	2.09	0.18	2.02
10	5.65	3.89	0.34	4.28
Mean	5.855	2.951	0.254	3.77

Where OC= Organic Carbon, TN= Total Nitrogen, Av P = Available phosphorous

3.2 Effect of NPS Fertilizer Rate on Yield and Yield Component of Tef

3.2.1 Plant Height

The analysis of variance showed that plant height was significantly ($P < 0.05$) influenced by the NPS fertilizer rate (Table 2). The highest plant height (83.59cm) of Tef was recorded from the application of 75% P-critical NPS fertilizer rate with recommended Nitrogen. The lowest plant height (51.34 cm) was recorded from the field without fertilizer, which was significantly inferior to all other treatments (Table 2). The increase in plant height with increasing NPS fertilizer could be attributed due to sufficient supply of nutrients which in turn contributed to increased vegetative growth since nitrogen plays a crucial role in the structure of chlorophyll a and P involved in the energy transfer for cellular metabolism.

3.2.2 Panicle Length

A Panicle length is one of the yield that contributes to grain yield. Crops with higher panicle length could have higher grain yield. Panicle length was highly significantly ($P < 0.05$) influenced by the NPS fertilizer rate. The highest Panicle length (29.05cm) of tef was recorded from the application of 100% P-critical NPS fertilizer rate with recommended Nitrogen. The lowest panicle length (19.20 cm) was recorded from the field without fertilizer, which was significantly inferior to all other treatments (Table 2). This result is in agreement (Feyera *et al.*, 2014) who report that balanced fertilization application and efficient utilization of nutrients lead to high photosynthetic productivity and accretion of dry matter, eventually increasing panicle /spike length.

Table 2. Effects of NPS Fertilizer Rate and Recommended Nitrogen on Yield and Yield Components of Tef

Treatment	pH (cm)	PL (cm)	Biomass kg ha^{-1}	Grain yield kg ha^{-1}
without fertilizer	51.34^{d}	19.20 ^{d}	2521 ^{e}	507^{d}
25% P-critical from NPS+ Recommended Nitrogen	74.92 ^{c}	25.55^{c}	5086^{d}	1209^{c}
50% P-critical from NPS+ Recommended Nitrogen	77.14b^{c}	26.16^{c}	5916 ^{c}	1375^{b}
75% P-critical from NPS +Recommended Nitro	83.59 ^{a}	28.75 ^{ab}	7079^{ab}	1548^{a}
100% P-critical from NPS+ Recommended Nitrogen	82.99 ^{a}	29.05^{a}	7509^{a}	1635^{a}
100% P-critical from DAP+ Recommended Nitrogen	80.66^{ab}	27.57^{b}	6808^{b}	1502^{ab}
$LSD_{0.05}$	3.61	1.39	621.28	144.91

CV (%)	9.4	10.5	20.9	21.9

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, PL= Panicle length, CV=Coefficient of variation, LSD=Least Significance Difference.

3.2.3 Biomass Yield

The analysis of variance showed that the biomass yield was significantly ($P < 0.05$) affected by NPS fertilizer rate (Table 2). The highest biomass yield (7509 kg ha^{-1}) was obtained from the application of 100% P-critical NPS fertilizer rate with recommended nitrogen and the lowest biomass yield (2521kg ha^{-1}) was obtained the unfertilized plots. The significant increase in biomass yield could be attributed due to the availability of macronutrients and some secondary nutrients formulated with the NPS fertilizer, which could increase the vegetative consequently the biomass yield. Similar significant increase in biomass yield was also observed for different application rates of NPS fertilizers which states that the increased in straw yield was attributed due to the proportional vegetative growth especially plant height (Feyera *et al*., 2014; Wakjira, 2018).

3.2.4 Grain Yield

Grain yield was significantly ($P < 0.05$) affected by NPS fertilizer rate. The highest (1635kg ha^{-1}) and the lowest (507 kg ha^{-1}) grain yield was obtained from the application of 100% P-critical NPS fertilizer supplemented with the recommended nitrogen and unfertilized plots respectively (Table 2). Grain yield increased consistently and significantly in response to the increasing rate of NPS fertilizer from nil up to the highest. The increased in grain yield from NPS fertilizer might be facilitated the uptake of other essential nutrients which helps to boost plant growth and yield. This result is in line with Wakjira, 2018 and Desta *et al.,* 2021, who reported that the maximum of grain yield of tef was recorded at the highest application of fertilizer rate.

3.2.5 Economic Analysis

Economic analysis indicated that the highest net benefit (72465.2 ETB ha^{-1}) and the highest marginal rate of return (MRR) (1110.46%) was obtained from the fertilizer application of 100% P-critical NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The lowest net benefit (23829ETB ha^{-1}) was obtained from unfertilized plots (Table 3). The MRR indicated that tef producers can get an extra of 11.1 ETB for 1.00 ETB investment in the NPS and N fertilizer application at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}).Therefore, the application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial and recommended for kuyu District.

Table 3. Marginal Analysis of Tef Yield as Affected by NPS Fertilizer with Nitrogen Rate

Treatment	Variable Input (Kg ha^{-1}) DAP/NPS	Urea	Unit price(ETB) DAP/NPS	Urea	TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
without fertilizer	0	0	0	0	0	507	47	23829	23829	
25% Pc NPS	35	185.55	561.5	2784.4	3345.9	1209	47	56823	53477.1	886.10
50% Pc NPS	70	171.1	1123.0	2567.5	3690.6	1375	47	64625	60934.4	1005.41
75% Pc NPS	105	189.62	1684.6	2845.5	4530.0	1548	47	72756	68226.0	980.06
100%Pc NPS	140	142.19	2246.1	2133.7	4379.8	1635	47	76845	72465.2	1110.46
100%Pc DAP	115.6	154.76	1854.6	2322.3	4177.0	1502	47	70594	66417.0	1019.59

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus, Rec. N = Recommended Nitrogen

4. Conclusions and Recommendations

Application of balanced NPS and nitrogen fertilizer significantly influenced most of the plant phrenology, growth parameters, yield, and yield components of tef. According to this study, NPS fertilizer rate based on calibrated phosphorus significantly influences the yield and yield component of tef which is at a promising level to sustain soil fertility and to tackle the problems. Therefore, the study was conducted to determine the effect of NPS fertilizer rate relative to the determined critical phosphorus for tef in Kuyu District.

The statically analysis of variance showed that plant height, panicle length, biomass, and grain yield was significantly ($P<0.05$) influenced by NPS fertilizer rate with N fertilizer. The highest plant height (83.59 cm), of tef was recorded from the application of 75% P-critical from NPS fertilizer rate with recommended nitrogen panicle length (29.05cm), biomass yield (7509 kg ha^{-1}) and grain yield (1635 kg ha^{-1}) of tef was recorded from the application of 100% P-critical from NPS fertilizer rate supplemented with recommended nitrogen whereas, the lowest value was recorded from the field unfertilized which was significantly inferior to all other treatments. Furthermore, the economic analysis depicted that the application of NPS fertilizer at the rate of 100% P-critical in NPS fertilizer with recommended nitrogen fertilizer (92 kg N ha^{-1}) for the production of tef was more economically beneficial for the district.

Therefore, farmers must be advised to use 100% PC from NPS fertilizer rate with recommended nitrogen for tef production in the district. Demonstration and further scale-up as well as verification of other districts of similar soil agro-ecology should be pre requisite.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Oromia Agricultural Research Institute for its financial support of this study. Other thanks also went to Fitche Agricultural Research Center for facilitating the successful completion of the study.

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