Sustainability in Environment
ISSN 2470-637X (Print) ISSN 2470-6388 (Online)
Vol. 7, No. 3, 2022
www.scholink.org/ojs/index.php/se

Original Paper

Verification of Soil Test Crop Response Based Phosphorus Fertilizer Recommendation for Tef in Debre Libanos District, North Shewa Zone, Oromia

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Received: May 4, 2022 Accepted: June 8, 2022 Online Published: June 17, 2022
doi:10.22158/se.v7n3p1 URL: http://dx.doi.org/10.22158/se.v7n3p1

Abstract

*The field experiment was conducted to verify the determined optimum amount of nitrogen (92 kg N ha $^{-1}$), critical P concentration (15 ppm) and P requirement factor (6.1) for tef production in Debre Libanos Districts. The experimental field was arranged with 3 treatments. The trial was carried out in Randomized Complete Block Design (RCBD) with seven replications over different Farmers field . Control (without fertilizer), Blanket recommendation (100kg Urea and100kg DAP) and soil test based fertilizer recommendation with recommended Nitrogen 92 kg ha $^{-1}$ were used as a treatment. The gross plot area was 10 * 10m and the space between plots was 0.7m. The required amount of seeds was weighed per plot by considering the recommended rate of tef seed per hectare. The result from this study indicate that an optimum rate of nitrogen (92 Kg N/ha) and soil test based phosphorus fertilizer recommendation was highly significantly influence plant height, panicle length, biomass and grain yield of tef. The highest plant height (82 cm) panicle (27.78 cm), biomass yield (4673kg ha $^{-1}$) and grain yield (1588 kg ha $^{-1}$) was recorded from the application of soil test based fertilizer recommendation in conjunction with recommended optimum Nitrogen. The results of the economic analysis showed that the maximum net return was obtained due to soil test based phosphorus fertilizer recommendation .As a result determined Pc and Pf through , site specific soil test crop response based fertilizer study could be profitable for tef production in the study area and other areas having similar soil type and agro-ecology.*

Keywords

optimum rate of nitrogen, soil test based, treatment, phosphorus fertilizer

1. Introduction

Tef, Eragrostis tef (Zucc.) Trotter is the major Ethiopian cereal grown for thousands of years [7] and currently grown on 2.5 million ha annually, and accounts for 30 per cent of total acreage and 19 per cent of gross cereal production [4]. It is the only cultivated cereal in the genus Eragrostis [1]. Tef is a highly versatile crop with respect to adaptation to different agro-ecologies, widely grown from sea level up to 2800 m above sea level (a.s.l.) under various rainfall, temperature, and soil conditions [19,18]. The crop has both its origin and diversity in Ethiopia [35] and plays a vital role in the country's overall food security. In addition, the straw is an important cattle feed source, and the high market prices of both its grains and the straw make it a highly valued cash crop for tef-growing smallholder farmers. However, the average mean grain yield of tef in this part of the country is below 1000 kg ha^{-1} [22] and variable, mainly due to nutrient stress.

In Sub-Saharan Africa (SSA), low and declining soil fertility due to net nutrient extraction by crops is responsible for low agricultural productivity and food insecurity [23]. Moreover, the rampant soil degradation and the consequent decline of its productivity due to loss essential plant nutrients is among the underlying reasons for poor crop yield and food insecurity [28]. Over 50% of the highlands in general and cropped areas of Ethiopia are in an advanced stage of land degradation [9]. Sub-Saharan Africa accounted for 3 percent of world fertilizer consumption in 2013 as compared to Asia that consumes 58.5 percent of the world total, the bulk of which is used in East Asia and South Asia [11]. In terms of per hectare fertilizer application Asia is in the first place in fertilizer application per hectare (150.7 kg ha^{-1}) [16]. While farmers in Sub-Saharan Africa estimated to have used 11 kg nutrients/ha in 2013, i.e. only 10% of the global average [8]. Therefore, there are still large areas where farmers use little fertilizer and mine their soil nutrient reserves. According to [31] the annual average nutrient loss for Sub-Saharan Africa was 26 kg N, 3 kg P, and 19 kg K ha^{-1} yr^{-1} the yearly equivalent of US$ 4 billion worth of fertilizers [8]. Because of all decline in the soil fertility is one of the major bottlenecks to agricultural production, productivity in the world particularly in Africa and specifically in Ethiopia [12]. Therefore, greater use of mineral fertilizers is crucial to increasing food production and slowing the rate of soil degradation in Ethiopia since severe soil nutrient depletion is a major bottleneck for boosting production and productivity of tef.

Phosphorous (P) is one of most limiting plant nutrients in the tropics [3] .it required in the early stages of growth [14], which is necessary for many plant processes including synthesis of phospholipids, energy transfer, and enzyme activation [15] for optimum crop production. Inadequate P availability is a major limitation to plant growth and development [30] and consequently global crop production [25]. It is estimated that 30–40% of global agricultural soils are limited by P availability and it is second only to nitrogen (N) in limiting agricultural productivity [34]. Phosphorous is deficient in about 70% of the soils in Ethiopia [21]. One of major constraints that are responsible for low yield is P deficiency ([2]. According to [26] the soils of the highlands are marginally to severely deficient in P. The Blanket fertilizer recommendations currently applied was released several years ago in Ethiopia, does not consider the differences in agro-ecological environments, are not suitable for the current production systems and for the foreseeable future [19]. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying same P fertilizer rate to their fields regardless of soil fertility differences. For this reasons, the blanket recommendation will make inefficient use of these expensive nutrients which contribute to the depletion of scarce financial resources, increased production costs and potential environmental risks [32].

Sound soil test calibration is essential for successful fertilizer program and crop production. Soil test based P-fertilizer calibration study on teff was conducted in Debre Libanos District during 2010 to 2012 cropping season to determine P-critical value, P-requirement factor and N-level for the District. Accordingly, FiARC has developed soil test based Pc (15 ppm) and Prf (6.10) for tef with 92 kg N ha^{-1} in Debre Libanos District. So this achievement should be verified for the districts to be scaled out and develop phosphorus fertilizer recommendation guide line for all tef growing areas in the district. Therefore the objective of this study was to verify the determined N-level, P-critical value and P-requirement factor determined for teff at the District.

2. Material and Methods

2.1 Description of the Study Area

The experiment was conducted in Debre Libanos Districts of North Shewa Zone, Oromia. The district is located at 89 km from the capital Addis Ababa. Geographical location existed between 09^0 36’0” and 09^0 45’0” North and 038^0 45’00” and $39^0$0’00” East. The altitude ranges between 1500 and 2700 (m.a.s.l). Agro ecological 75% of the district is highland 15% is midland and 10% is lowland. The main rainy season of the study area is between May and September in which mean annual rainfall is about 1000 mm that ranges from 800 to 1200 mm. The maximum and minimum annual temperature is 23^0C and 15^0C, respectively.

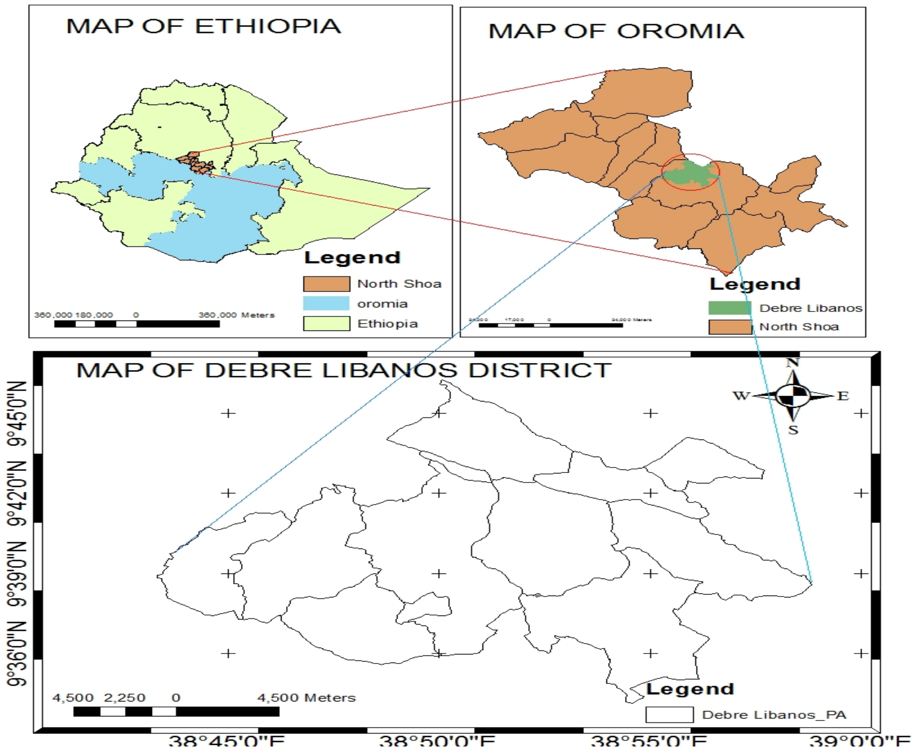

Figure 1. Map of the Study Area

2.1.1 Site Selection, Soil Sampling and Analysis Methods

Tef production potential kebeles (small administrative unit) were selected from the District. Before planting 20 (Twenty) surface composite soil samples were collected from each field for analysis at a depth of 0-20 cm in a zig zag methods. Soil samples were collected using auger. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through 2 mm sieve for further analysis in the laboratory [10]. The collected soil samples were analyzed for pH (H_2O) in the suspension of a 1: 2.5 soil to water ratio using a pH meter [27] and Available P was determined by the Olsen's method using a spectrophotometer [24]. Then 7 farmer's field was selected based on the analyzed soil sample results in which the soil pH above 5.5, available soil phosphorus below critical phosphorus (Pc) considering willingness of the farmers to handle the experimental field

2.1.2 Experimental Procedures

The experimental field was arranged with 3 treatments. The trial was carried out in Randomized complete block design (RCBD) with seven replications. Farmers used as replications. The treatment were includes control (without fertilizer), Blanket recommendation (100kg DAP & 100kg urea) and soil test based fertilizer recommendation with recommended Nitrogen 92 kg ha^{-1}. The gross plot area was 10 * 10m and the space between plots was 0.7m. The required amount of seeds was weighed per plot by considering the recommended rate (25kg/ha) of tef seed per hectare. Urea and DAP (Di ammonium Phosphate) was used as source of nitrogen and phosphorus containing fertilizers. A tef variety (Kora) was used. Uniform field management practices for all plots were conducted. The determined P-critical value (15 ppm) and phosphorous requirement factor (6.10 ppm) was used to calculate the rate of 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

2.1.3 Data Collection

Tef 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 subtracting the grain yield from the total above ground biomass 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 was recorded.

2.1.4 Data Analysis

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

2.1.5 Economic Analysis

Partial budget analysis was done to identify economic feasibility among the treatment. The average open market price (Birr kg^{-1}) of tef, at field level and fertilizers was used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MRR) should be 100 % [5], which is suggested to be realistic. This enables to make recommendations from marginal analysis. Marginal rate of return (MRR) were calculated by using the formula given blow;

$$\mathrm{MRR} = \frac{\text{Net Income From Fertilized Field} - \text{Net Income From Unfertilized Field}}{\text{Total Variable Cost From Fertilizer Application}}$$

3. Result and Discussions

3.1 Soil Reaction (pH) and Available Phosphorus of Experimental Field

The analyzed soil samples indicated that, the soil pH (H_2O) of the study area is (6.01), which is moderately to slightly acidic with the value ranged from 5.87 to 6.29 according to the ratings suggested by [33]. Thus, the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils is 4.71ppm, which is very low to low with the value ranged from 2.78 to 6.94 ppm according to the rating given by [6]. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

3.1.1 Response of Grain Yield of tef to treatment

The analysis of variances indicated that, there was a highly significant variation ($p < 0.01$) among the treatments on plant height, panicle length, biomass and grain yield. Accordingly, the highest plant height (82 cm) and panicle length (27.78 cm) was recorded from the application of soil test based fertilizer recommendation. While the lowest plant height (46.56 cm) and panicle length (17.67 cm) was registered from the treatments without fertilizer application. In addition, the maximum biomass yield (4673 kg ha $^{-1}$) and grain yield (1588 kg ha $^{-1}$) was recorded from the soil treated with the soil test based fertilizer recommendation. The results clearly showed that, tef yield and yield components were significantly increased with the application of 92 Kg N ha $^{-1}$ and site specific fertilizer recommendation over the blanket fertilizer recommendation. The results of this study are consistent with findings of [16; 20; 17] who reported that the highest values on yield and yield component of tef was recorded under the application of site specific fertilizer recommendation over blanket recommendation.

Table 1. Effects of Blanket and Soil Test Based Fertilizer Recommendation on Plant Height, Spike Length, Biomass and Grain Yield of Tef

Treatment	Plant height (cm)	Panicle length (cm)	Biomass (kg ha^{-1})	Grain Yield (kg ha^{-1})
Without fertilizer	46.56^{b}	17.67^{b}	2160^{b}	764^{b}
Blanket Recommendation	77.72^{a}	24.58^{a}	3886^{a}	1031^{b}
Soil test based fertilizer recommendation	82^{a}	27.78^{a}	4673^{a}	1588^{a}
$LSD_{0.05}$	8.597	3.36	889.2	278.1
CV(%)	5.5	6.4	17.1	19.2

Where: LSD= Least Significant Difference, CV (%) = Coefficient of Variation

3.1.2 Partial Budget Analysis

To estimate the economical significant of the different fertilizer rates, partial budget analysis were employed to calculate the Marginal rate of return (MRR) to investigate the economic feasibility of fertilizers. Based on actual unit prices during the year 2020 harvesting season farm gate price of 43 ETB (Ethiopian Birr) per kg of teff, 16.35 and 15.01 Birr per kg of DAP and Urea, respectively were used to calculate variable cost. The economic analysis showed that the highest net income (61106.35 ETB per ha) and marginal Rate of Return (393.64%) was obtained from soil test based fertilizer recommendation (Table 3). Thus, the MRR showed that it would yield 3.94 birr for every birr invested. Therefore, soil test based fertilizer recommendation record the highest MRR that is in acceptance range. So, farmers and other end users in the study area advised to use this soil test crop response-based recommended fertilizer which is cost effective , economically feasible and environmentally safe.

Table 2. Partial Budget Analysis for Verification of Tef in Debre Libanos District

Treatment	Variable Input (Kg ha^{-1})		Unit price(ETB)		TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
	DAP	Urea	DAP	Urea						
without fertilizer	0	0	0	0	0	764	43	32852	32852.00	
Blanket fertilizer	100	100	16.35	15.01	3135.52	1031	43	44333	41197.48	266.16
STBPFR	398.62	44.02	16.35	15.01	7177.65	1588	43	68284	61106.35	393.64

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return.

4. Discussion

The field experiment was conducted to verify the determined optimum amount of nitrogen (92 kg N ha^{-1}), critical P concentration (15 ppm) and P requirement factor (6.1) for tef production in Debre Libanos District. An optimum rate of nitrogen (92 Kg N/ha) and soil test based phosphorus fertilizer recommendation was highly significantly influence plant height, panicle length, Biomass and grain yield of tef. Accordingly, the highest plant height (82 cm) panicle length (27.78 cm), biomass yield (4673 kg ha^{-1}) and grain yield (1588 kg ha^{-1}) was recorded from the application of soil test based fertilizer recommendation in conjunction with recommended optimum Nitrogen. The economic analysis also showed that the highest net benefit (61106.35 ETB) was obtained from site specific soil test based fertilizer recommendation with marginal rate of return 393.64% which is greater than the acceptable minimum rate of return (100%). Therefore, site specific soil test based crop response fertilizer recommendation could be recommended and thus the determined Pc and Pf for tef production could be demonstrated and scaled up in study area (Debre Libanos District) and verified in other districts in the zones those having similar soil type and agro-ecology.

Acknowledgement

The authors are grateful to Fitche Agricultural Research Center, for facilitating the research and Oromia Agricultural Research Institute (IQQO) for funding the experiment**.**

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