Response of Tef (*Eragrostis Tef*) to Different Rates of Nitrogen and Phosphorous in Gumara Maksegnit Watershed

Baye Ayalew, Meron Lakew and Ayalew Addis

Amhara Agricultural Research Institute, Gondar Agricultural Research Center, P.O.Box 1337 Gondar, Ethiopia.

Corresponding Author: Baye Ayalew, e-mail: ayalew.baye@yahoo.com

Abstract

Nitrogen, phosphorous and potassium are the essential elements required for plant growth in relatively large amounts. However, deficiencies of nitrogen and phosphorus are common. Soil nutrients become depleted due to leaching of nitrogen, fixation of phosphorous, soil erosion, and removal by crops. To maintain a high crop production level, the nutrient status of the soil has to be maintained through crop rotation, addition of manures or application of inorganic fertilizers). Synthetic fertilizers are important inputs in agricultural production system because they supply the required nutrients in a readily available form for immediate plant use. An experiment was conducted in Gondar Zuria district, Abakaloye and Dinzaz villages, Gumara-Maksegnit watershed with the objective of determining biologically and economically optimum level of N and P rates for tef production. The experiment was carried in two groups of homogeneous sites Vertisols (heavy soil) and Cambisols of the area. Four levels of nitrogen (0, 46, 69 and 92 kg N ha^{-1}) and four levels of phosphorus fertilizer (0, 20, 30 and 40 kg P ha^{-1}) combined factorially. A randomized complete block design with three replications was used. Growth and yield parameters were collected and analyzed using SAS computer software. The results showed that there was a statistically significant difference among treatments in both biomass and grain yield ($p < 0.05$). Application of 20 kg P ha^{-1} *and 46 kg N* ha^{-1} *significantly increased grain yield and biomass yield. Therefore, 20 kg P* ha^{-1} *and 46 kg N* ha^{-1} *are recommended to tef production.*

Keywords*:* Gonder-Zuria, nutrient, tef production, vertisols, yield

Introduction

Nitrogen, phosphorous and potassium are the essential elements required for plant growth in relatively large amounts. However, deficiencies of nitrogen and phosphorus are common. Soil nutrients become depleted due to leaching of nitrogen, fixation of phosphorous, soil erosion, and removal of nutrients by crops (Oldeman *et al.,1993)*. To maintain a high crop production level, the nutrient status of the soil has to be maintained through crop rotation, addition of manures and /or application of inorganic fertilizers (WRI, 1997). Synthetic fertilizers are important inputs because they supply the required nutrients in a readily available form for immediate plant use.

Tef is the most important cereal crop and serving millions of people as a staple food in Ethiopia. (Chibo et al., 2002) reported that tef contains 11% protein and is an excellent source of essential amino acids, especially lysine, the amino acid that is most often deficient in grain foods. Tef contains more lysine than barley, millet, and wheat and slightly less than rice or oats. They further mentioned that tef is also an excellent source of fiber and iron, and has many times the amount of calcium, potassium and other essential minerals found in an equal amount of other grains. They also noted that tef is nearly gluten-free and alternative grain for persons with gluten sensitivity. Tef may also have applications for persons with Celiac Disease. It contains 11% total carbohydrates, 24% dietary fiber, 10% thiamine, 2% riboflavin, 4% niacin, 8% calcium and 20% iron and is free from saturated fat, sugar and cholesterol (Purcell Mountain Farms, 2008). Gilbert (1997) indicated that tef straw from threshed grains is considered to be excellent forage, superior to straws from other cereal species. Tef straw provides an excellent nutritional product in comparison to other animal feed and is also utilized to reinforce mud or plasters used in the construction of buildings (Doris, 2010). Although tef is adapted to a wide range of environments and diverse agro-climatic conditions, it performs excellently at an altitude of 1800-2100 m a s l, annual rainfall of 750-850 mm, growing season rainfall of 450-550 mm, and a temperature of 10 0^{C}-27 0^{C} (Seifu Ketema, 1993). It does well on clay loam and clay soils, which retain moisture during growing seasons. Tef is well suited on soils with a moderate fertility level and can tolerate moderate waterlogged conditions (National Soil Service, 1994). It is also widely grown in the Southern Region of Ethiopia, where early varieties like Dhabi and Bunigne are commonly produced during belg (March-June) rainy season, whereas medium to late varieties are dominantly produced during the main rain/meher (July- October) season According to CSA

(1999), tef, covers the largest cultivated land as compared to cereals, pulses and oils, with an average annual production of 1.87 million tonnes. Out of the estimated total cultivated land (8.216 million ha), it covered 31% in 1996/1997, 32% in 1997/1998 (CSA1999), and 25.84% in 2000/01 (CSA, 2002). From the figures above one can understand that, although the percentage of land under tef gradually decreases, the total area is continued to increase still as a result of more and more new land is being cleared and put under cultivation each year. Despite the large-scale production and various merits, tef production and productivity have been far below the potential. Currently, the average national productivity is 0.92 t ha^{-1}, which is very low as compared to other small grain cereals grown in Ethiopia. Tef is produced in large plots, which is difficult for farmers to apply organic fertilizers to improve soil fertility. To feed the ever-increasing population and generate income, continuous cultivation of land became a common practice in major tef producing areas, which eventually led to soil fertility decline and subsequent reduction of crop yields. Thus, as noted by Mwangi (1995) the use of synthetic fertilizer is critical to increase crop yield. In many cases, farmers are being forced to either not use or use low rates of fertilizer due to high fertilizer costs. Use of fertilizers recommendation rate irrespective of soil variations is one of the discouraging factors to farmers. Thus, cost-effective use of fertilizers in Ethiopia is very crucial. Fertilizer recommendations are site, crop and soil specific; hence fertilizer rates should also be established for each crop.

Soil fertility studies and crop improvement have brought remarkable changes in crop production, particularly in tef. Decreases in soil status decreases productivities of various cultivars in which their nutritional demand is dife erent and increasing. Dubale (2019) elucidates that fertilizer rate studies are dynamic and increasing from time to time. Fertilizer rate recommendations need to be soil test based and should be done repeatedly for any cultivar to maximize the inherent potential yield of the crop (Dubale, 2019). However, 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). Therefore, this research was carried out for two consecutive years to assess the economic and biological optimum rates of NP levels for the production of tef.

Materials and methods

Description of the study area

The study area is located between 37° 33’ to 37° 30’ North latitude and 12° 23’ to 12° 30’ East longitude (figure 1) in Gondar zuria District, North Gondar administrative zone, Amhara National Regional State of Ethiopia.

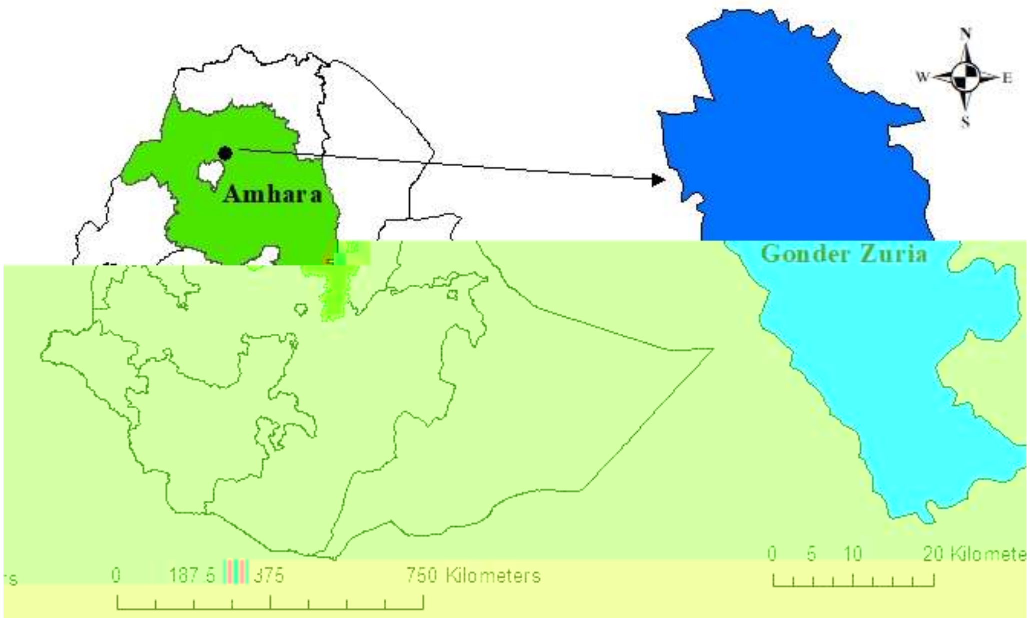

Figure 5. Map of the **s**tudy area

The Altitude of the area ranges from 1920 to 2400 m a.s.l (Woina Dega (cool semi-humid) and Dega zones (cool, above 2,400 m.a.s.l). The annual rainfall is 1052 mm with a variation between 758 mm and 1440 mm and has a monomodal pattern. Rainfall starts in June and ends in mid-September. The annual temperature varies from a minimum of 13.3 o C to a maximum of 28.5o C. Based on rainfall and PET calculations, the length of the growing period (LGP) is expected to vary from 110 to 120 days. The major soil type is Vertisol according to USDA soil classification.

Experimental design and procedures

The study was carried out during two cropping seasons (2014 and 2015). The field studies were carried on a farmer’s field with two locations using factorial combinations of nitrogen and phosphorous fertilizers. Urea (46% N, TSP (46% P2O5) and NPS (19-38-7) were used as a source of nitrogen and phosphorus nutrients. Quncho variety (DZ-Cr-387-RIL 355), which is a high-yielding white-seeded cultivar adapted to a wide range of altitudes was used for the experiment. The treatments were a factorial combinations of four levels of nitrogen (0, 46, 69 and 92 kg N ha-1), and four levels of phosphorus (0, 20, 30 and 40 kg P ha-1). The experiment was laid in a randomized complete block design (RCBD) with three replications. The size of each experimental plot was 3 m by 3 m. Distance between plots and blocks were 0.5 and 1.5 m, respectively as well as 20 cm between rows. Experimental plots were kept weed-free uniformly.

Data Collection

Plant height was measured at physiological maturity from the ground level to the tip of the panicle from ten randomly selected plants in each plot. While panicle length which is the length of the panicle from the node where the first panicle branches emerge to the tip of the panicle was determined from an average of ten selected plants per plot. Furthermore, grain yield was measured by harvesting the crop from the net middle plot area of 2.5 x 2.5 m to avoid border effects. At maturity, the whole plant parts, including leaves and stems, and seeds from the net plot area were harvested and after drying, the biomass was measured. Straw yield was calculated after threshing and measuring the grain yield, the straw yield was obtained by subtracting the grain yield from the total above-ground biomass. Finally, harvest index was calculated by dividing grain yield by the total above-ground air-dry biomass yield.

Soil Sampling and Analysis

Soils were sampled from experimental sites for their Physico-chemical properties analysis from one representative composite sample which were taken 0 to 20 cm depth from the entire field before planting and after harvest from each plot. Samples were analyzed for the following parameters viz., pH, organic carbon, cation exchange capacity, and available P from the representative bulk soil sample before planting. Soil pH was estimated by potentiometric method at soil: water ratio of 1:2.5 (Van Reeuwijk, 1992). Cation exchange capacity was determined by 1M ammonium acetate method at pH 7 (Chapman, 1965) whereas organic carbon was determined by the dichromate oxidation method (Walkley and Black, 1934) and available P was analyzed by Olsen method (Olsen et al., 1954) and determined colorimetrically by the ascorbic acid- molybdate blue method (Watanabe and Olsen, 1965). Ca++ and Mg++ values were found out from Atomic Absorption Spectrophotometer reading while Na+ and K+ were determined using flame photometer.

Data analysis

The data collected on different parameters were subjected to statistical analysis using PROC ANOVA function of SAS program. After performing ANOVA, the differences between the treatment means were compared by LSD test at 5% level of significance.

Results and discussion

Intial soil properties of the study sites

The soil pH analysisresult showed that the soil was slightly acidic to neutral . According to Tekalign (1991), the experimental areas were low in total Nitrogen and available Phosphorus () (Table 1). This result indicated that both nitrogen and phosphorus nutrients may be a yield-limited factor in the area for Tef production.

Table 1. Soil analysis result before planting

Soil properties	Results
pH (H_2O)	6.58
Total Nitrogen (%)Kjeldhal	0.07
Available P (PPM)	7.43
OC (%)Walkely	1.2
Soil texture	Sandy clay

Table 2. Soil analysis result after harvesting

Treatments (P2O5, N) (kg/ha)	PH H_2O	EC ms/cm	TN (%) Kjeldhal	Available P PPM	OC (%) Walkely
(0,0)	6.97	0.04	0.07	8.05	1.94
(46,0)	6.97	0.03	0.07	12	2.25
(69,0)	6.98	0.03	0.07	17	1.92
(92,0)	6.98	0.03	0.08	21.5	2.35
(0,46)	7	0.03	0.06	7.18	1.92
(46,46)	6.95	0.03	0.07	7.61	2.28
(69,46)	6.97	0.04	0.08	10.5	1.58
(92,46)	6.88	0.04	0.08	16.2	2.52
(0,69)	6.97	0.04	0.08	12.5	2.11
(46,69)	6.94	0.04	0.07	6.32	1.97
(69,69)	6.91	0.03	0.07	10.6	2.3
(92,69)	7.01	0.03	0.07	16	2.47
(0,92)	6.88	0.07	0.08	6	1.94
(46,92)	6.95	0.04	0.07	7.49	2.06
(69,92)	6.89	0.04	0.08	9.81	2.04
(46,92)	6.97	0.03	0.07	13.1	1.14
(69,92)	6.96	0.04	0.07	12.5	1.94

The soil analysis result after harvest indicated that (Table 2) the availability of P increasing with an increasing effect of phosphorus fertilizer application and while there was no significant change in soil pH . This might be because of the soil fertilizer application and the organic matter content was affected by the treatment.

Straw yield

Straw yield was significantly ($P \leq 0.05$) affected by the main effect of N and P application as well as their interaction. Generally, the combined application of N and P resulted in increased straw yields (Table 3). Thus, the application of 46 kg N ha-1 and 20 kg P ha-1 provided the highest (3135.4 kg ha-1) straw yield, with the yield increment of 129% compared to the control. In contrast, the lowest (1396.4 kg ha-1) straw yield was recorded from the control treatment (unfertilized plot). Consistent with this finding, Melesse (2007) reported that wheat cultivars produced higher straw yields in response to the combined application of higher rates of N and P. The increased straw yield might be due to the effect of high N application on the production of effective large numbers of tillers, increased plant height, and panicle length (provid the yield component data here; plant height, panicle length). Temesgen (2012), Haftom et al., (2009) and Mitiku (2008) indicated that the highest straw yield was obtained in response to the application of higher rates of N application, which enhanced the production of significantly longer panicle sizes and taller plants, and as a result greater biomass yield.

Table 3. Straw yield (kg ha^{-1}) of tef as affected by N*P interaction at Gondar Zuria, 2014 – 2015

N (kg ha^{-1})	P (kg ha^{-1})				
	0	20	30	40	Mean
0	1396.4i	2106.4ef	2266.2de	2294.6de	2015.9
46	1716.8fghi	3135.4a	2505.4bcd	2468.1cde	2456.4
69	1597.9hi	2286.4de	2436.5cde	2468.7cde	2197.4
92	1708.6ghi	2600.4bcd	2367.2cde	2089.0efg	2191.3
Mean	1604.9	2532.2	2393.8	2330.1	
N *P , LSD(5%)=201.1			CV (%) =18.75		

Grain yield

Grain yield is the result of many complex morphological and physiological processes occurring during the growth and development of crops (Khan et al., 2008). The analysis of variance showed that the grain yield of tef was significantly ($P \leq 0.05$) influenced by the main effect of N and P fertilizer rate as well as by the interaction of N and P rates (Table 4).

The maximum grain yield (1681.1 kg ha-1) was obtained from the application of 46 kg N ha-1and 20 kg P ha-1while the minimum grain yield of tef was recorded from the unfertilized plots. Grain yield significantly increased ($P \leq 0.05$) from 708.6 to 1681.1 kg ha-1with the increase in the levels of N/P from the control (0/0 N/P) to 46 kg N ha-1along with 20 kg P ha-1, but decreased with further increase in applied N and P fertilizer. The magnitude of increase in grain yield due to application of 46 kg N ha-1and 20 kg P ha-1was higher by 137 % than the control. This might be due to the uptake of balanced amounts of nitrogen by plants throughout the major growth stages; enhanced synchrony of the demand of the nutrient for uptake by the plant and its availability in the root zone in sufficient amounts. Temesgen (2001) reported that the application of different levels of N significantly affected grain yield of tef on the farmer's field. In this experiment, the reduction in grain yield with higher N and P levels beyond 46 kg N and 20 kg P ha-1might be mainly related to the reductions observed in the yield components and thereby decreased grain yield. Consistent with this suggestion, Reinke et al. (1994) indicated that where the grain yield response is negative, yield reduction is primarily caused by a reduction in the proportion of the number of filled spikelets per panicle. Singh et al. (1995) also reported a decrease in grain yield of rice with an application of high doses of N fertilizer.

Table 4. Grain yield (kg ha^{-1}) of tef as affected by N*P interaction at Gondar Zuria, 2014 – 2015.

Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})				
	0	20	30	40	Mean
0	708.6h	1005.8de	1257.2bc	1179.4cd	1037.8
46	832.6fgh	1681.1a	1142.0cd	1312.0b	1241.9
69	966.1efg	1039.0de	1015.8ef	1105.3cde	1031.6
92	921.3efg	1079.6de	1042.4de	947.5efg	997.7
Mean	857.2	1201.4	1114.4	1136.1	
N *P , LSD(5%)= 99.8			CV (%) =18.53		

Effects of NP fertilizer on economic feasibility of tef production

The higher net return EB 19043.8 Birr ha-1 with a marginal rate of return of 1221% was obtained with the application of 46/20 kg N/P ha-1. Thus, 46 kg N ha-1 combined with 20 kg P ha-1 fertilizer rate application are the most economically feasible for tef growers compared to the other levels.

Table 5. Effects of NP rates on economic feasibility of tef production of at Gondar Zuria.

N ($kgha^{-1}$)	P ($kgha^{-1}$)	AGYT ($kgha^{-1}$)	TVC (Birr)	Revenue (Birr)	Net benefit (Birr)	Value to cost ratio	Marginal rate of return (%)
0	0	637.7	9885	2085	7800	3.7	
0	20	905.2	14031	3022.5	11008.4	3.6	1000
46	0	749.3	11615	3470	8144.8D	2.3	
0	30	1131.5	17538	3960	13577.9	3.4	111
69	0	869.5	13477	4162.5	9314.6D	2.2	
46	20	1513	23451	4407.5	19043.8	4.3	1221
92	0	829.2	12852	4855	7997.1D	1.6	
0	40	1061.5	16453	4897.5	11555.1D	2.4	
69	20	935.1	14494	5100	9394.1D	1.8	
46	30	1027.8	15931	5345	10585.9D	2	
92	20	971.6	15060	5792.5	9967.9D	2	
69	30	914.2	14170	6037.5	8132.9D	1.3	
46	40	1180.8	18302	6282.5	12019.9D	1.9	
92	30	937.8	14536	6730	8505.9D	1.4	
69	40	994.8	15419	6975	8443.9D	1.2	
92	40	852.8	13218	7667.5	6250.1D	0.9	

** Price of Urea =13.85 Birr/kg, TSP=18.75 Birr/kg, DAP=14.35 Birr/kg, Price of tef=15.50 Birr/kg and price of tef for seed=20 Birr/kg, AGYT= Adjusted grain yield of tef and D=Dominated*

Conclusion and recommendation

Application of 20 kg ha-1P and 46 kg ha-1N significantly increased grain yield and biomass yield. The results showed that there was a statistically significant difference among treatments in both biomass and grain yield ($p < 0.05$). The treatment with better grain yield was found economically optimal. Therefore, 20 kg ha-1P and 46 kg ha-1N are recommended to tef production.

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