

Use of Balanced Nutrients for Better Production of Teff (Eragrostis tef (zucc.) at Bensa in Southern Ethiopia

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Abstract
A number of blended fertilizers containing multi-nutrients are formulated to be used in soils of different areas of Ethiopia; however, they are not evaluated for their effectiveness and rate of application in different crops and soils. Therefore, this study was conducted to provide site and crop specific balanced nutrient recommendations for teff production at Bensa in southern Ethiopia. The experiment was conducted in a randomized complete block design (RCBD) with seven treatments replicated across five farmers. The treatments included (1) 64 kg N + 30 Kg P/ha (recommended amount of N and P) (2) 28 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha (3) 46 kg N + 20 kg P + 16 kg S + 2.6 kg Zn/ha (4) 64 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha (5) 28 kg N + 30 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha (6) 64 kg N + 30 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha (7) 64 kg N + 20 kg P + 16 kg S + 2.6 kg Zn/ha. Teff variety cross-37 was drilled in rows on a 4 × 4 m plot. The sources of the nutrients were TSP, Urea and two different types of blended fertilizers. The first blended fertilizer contains 14 kg N + 9 kg P + 12.5 kg K+ 6.5 kg S + 1.2 kg Zn+ 0.5 kg B/100 kg of the fertilizers, while the second type of blended fertilizer contains 23 kg N + 10 kg P + 8kg S + 1.3 kg Zn/100 kg of the fertilizer. Data including tiller number, straw yield, and biomass and grain yields were collected and analyzed using Proc GLM procedures in the SAS 9.3 program and Least Significant Difference (LSD) test was used for mean separation. Economic analysis was performed using partial budget, dominance and marginal analyses to investigate the economic feasibility of the blended fertilizers for teff production. The result of data analysis indicated that application of unbalanced nutrients (only N and P) even at recommended rate gave significantly lower yield than the balanced nutrients. Besides, application of balanced nutrients with improper proportion also gave lower teff yield. Therefore, for better teff production at Bensa, it is important to apply balanced nutrients with their proper proportion. Thus, application of 64kgN+30kgP+25kgK+13kgS+2.4kgZn+1kgB/ha is recommended for production of teff at Bensa.
Keywords: balanced nutrients, teff, blended fertilizers, nutrient depletion, multi-nutrients

Introduction

The population of Ethiopia is currently growing at a faster rate than growth in food production. Severe depletion of nutrients is one of the major factors for the slower growth of food production. The annual net loss of nutrients is estimated to be more than 40, 6.6 and 33.2 kg ha^{-1} N, P and K, respectively (Scoones and Toulmin, 1999). Problems of declining soil fertility are widespread in Ethiopia causing large yield loss in different areas of the country (Zingore, 2011). Continuous cropping, high proportions of cereals in the cropping system, and the application of suboptimal levels of mineral fertilizers and organic nutrient sources aggravate the decline in soil fertility (Tanner et al., 1991; Hailu et al.,1991; Workneh and Mwangi, 1992), which results in lower crop yields and biomass production (Selamyihun et al., 2005 and Nigussie et al, 2007). The authors attributed the use of lower amounts of organic nutrient sources to competing uses for fuel and fodder. Nutrient loss due to the use of dung and crop residues for fuel, which otherwise could be added to the soil, is equivalent to the total amount of nutrients in commercial fertilizers being used in Ethiopia (PIF, 2010). Removal of total crop residues though harvesting also removes cations and organic matter, which can help neutralize soil acidity and maintain soil productivity. Nutrients removed through crop harvests are at least four times more than nutrients returned to the soil in the form of manure and fertilizer, resulting in excessive negative nutrient balance in croplands. There is a critical need to reverse the trend of soil nutrient depletion and meet the food requirements of the growing populations.

Nutrient mining caused by the use of unbalanced (the use of N and P only) and lower rate of nutrients have great contribution to the emergence of multi nutrient deficiency in Ethiopian soils (Abyie et al., 2003, Beyene, 1984; Wassie et al., 2011). EthioSIS (2013) reported that N, P, sulphur, boron and zinc were deficient in most soils of Ethiopia, whereas potassium, copper, manganese and iron were observed to be deficient in some soils of the country. Although N and P have been continuously used for crop production, yields were held back due to the limiting effects of the other deficient nutrients (unbalanced nutrient condition). Since there is no alternative to providing balanced crop nutrition for producing foods of high nutritional quality with sustainable economic and environmental yield levels, it is time to move beyond the concept of managing single nutrients (Mikkelsen, 2004). Thus, it is critical to reverse the multi nutrient deficiencies in order to boost crop yields and meet the food demand of the ever increasing population.

Farmers in Ethiopia use both inorganic and organic nutrient sources to counteract the decline in soil fertility. However, despite significant rise in total fertilizer import from 250,000 tons in 1995 to 500,000 tons in 2012 (CSA, 2012), the intensity of the fertilizer use has increased only from 31 kilograms per ha in 1995 to 36 kilograms per ha in 2008 (Alem et al., 2008; Fufa and Hassen 2005) being mainly attributed to lack of data on crop nutrient requirements. Although effective use of chemical fertilizer is the main way to ensure food security in short run, the current fertilizer application rate in Ethiopia is too low to improve production ensure food security.Blanket and unbalanced applications of nutrients (64 kg N and 20 kg P ha^{-1}) have been used all over the country irrespective of soil and crop types, crop varieties and agro-ecological zones, resulting in wide gap between the potential and the actual crop yields. This situation calls for the need of site and crop specific, and balanced nutrients recommendation.

The use of fertilizers that contain multi-nutrients is of great importance to ensure the supply of all or most of the nutrients required by crops. Experience in Malawi provides a striking example of how N fertilizer efficiency for maize can be raised by providing appropriate micronutrients on a location-specific basis. A study in Malawi revealed that application of N, P, K, S, Zn and B, increased maize yields by 40% over the use of only recommended amounts of N and P (John et al., 2000). Application of N, P and also significantly increased potato yield over the use of only recommended amounts of N and P in southern Ethiopia (Wassie and Shiferaw, 2011). A number of blended fertilizers containing multi-nutrients are formulated to be used in soils of different areas of Ethiopia. It is worthy to evaluate these fertilizers for their effectiveness in and determine rate of application for different crops and soils before starting to use. Therefore, this study was conducted to provide site and crop specific balanced nutrient recommendations for teff production at Bensa in southern Ethiopia.

Materials and Methods

The experiment was conducted on farmers' fields at Bensa district in Southern Nations Nationalities and People Regional State (SNNPRS) during 2014 and 2015 cropping seasons. The experimental site was located between 06.48611N latitude and 038.77166 E longitude at an altitude of about 1992 meter above sea level. The experiment was conducted in a randomized complete block design (RCBD) with seven treatments replicated across five farmers. The treatments included (1) 64 kg N + 30 Kg P/ha (recommended amount of N and P) (2) 28 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha (3) 46 kg N + 20 kg P + 16 kg S + 2.6 kg Zn/ha (4) 64 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha (5) 28 kg N + 30 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha (6) 64 kg N + 30 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha (7) 64 kg N + 20 kg P + 16 kg S + 2.6 kg Zn/ha. Teff variety cross-37 was drilled in rows on a 4 × 4 m plot. The sources of the nutrients were TSP, Urea and two different types of blended fertilizers. The first blended fertilizer contains 14 kg N + 9 kg P + 12.5 kg K+ 6.5 kg S + 1.2 kg Zn+ 0.5 kg B/100 kg of the fertilizers, while the second type of blended fertilizer contains 23 kg N + 10 kg P + 8kg S + 1.3 kg Zn/100 kg of the fertilizer. Sources of N were the blended fertilizers and Urea, whereas sources of P were TSP and the blended fertilizers. Those treatments, which contain the recommended amount of N and/or P within the blended fertilizers, received additional amounts of these nutrients from Urea and TSP, respectively. All doses of TSP and the blended fertilizers were in raw applied during planting, whereas Urea was top dressed 45 days after planting. All necessary management practices were equally applied for all treatments. Data including tiller number, straw yield, biomass and grain yields were collected. Analysis of variance (ANOVA) was carried out using Proc GLM procedures in the SAS 9.3 program (SAS Institute Inc., Cary, NC USA) and Least Significant Difference (LSD) test was used for mean separation.

Economic analysis was performed using partial budget, dominance and marginal analyses to investigate the economic feasibility of the blended fertilizers for teff production. The average yield was adjusted downwards by 10% assuming that farmers could get 10% less yield. The average open market price (Birr kg^{-1}) for teff and the official prices of Urea, TSP and the blended fertilizers were used for analysis. For a treatment to be considered a worthwhile option to farmers, 100% rate of return (MARR) was considered as suggested by (Amanuel Gorfu et al., 1991).

Results and Discussion

The result of data analysis indicated that applying only N and P is not adequate for better teff production at Bensa. Additional nutrients such as K, S, Zn and B are required to boost the production (Table 1).

Table 1. Response of teff to application of different fertilizers

No	Treatments	Grain yield (kg/ha)	Biomass (t/ha)	Straw yield (t/ha)	No. of tillers
1	64 kgN + 30 kg P/ha(recommended amount of NP)	1187.0bc	4.39b	3.27b	6.83ab
2	28kgN+18kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	1081.3c	4.32b	3.20b	6.70ab
3	46kgN+20kgP+16kgS+2.6kgZn/ha	1243.3bc	5.01ab	3.83ab	6.17b
4	64kgN+18kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	1365.4ab	5.83a	4.50a	7.17a
5	28kgN+30kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	1207.4bc	4.69ab	3.52ab	7.30a
6	64kgN+30kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	1502.5a	5.46ab	4.13ab	6.83ab
7	64kgN+20kgP+16kgS+2.6kgZn/ha	1280.8abc	4.69ab	3.43b	6.03b
	CV (%)	15.46	19.82	24.25	10.26
	LSD 5%	232.44	1.15	1.06	0.82

According to soil fertility map of Southern Nations Nationalities and Peoples Region, these nutrients were recommended to produce crop on the soils of Bensa area. Avoiding only K and B, while N, P, S and Zn were applied, grain yield of teff was significantly reduced indicating that teff production on the soils of the study sites require application of balanced nutrients. Mikkelsen (2004) also indicated that crop productivity is clearly influenced by having the correct balance of essential nutrients present in the soil and crop growth and quality would be adversely impacted when any plant nutrient is lacking. Zingore (2011) reported that balanced fertilization is necessary to achieve high crop productivity on degraded soils. The response of teff was very low to the application of only N and P, which is attributed to deficiency of other plant nutrients (FAO, 2006) indicating that crops require balanced essential nutrients to complete their life cycle. The result also shows that the amount of N and P to be applied is critical. Although balanced nutrients were applied, yield was significantly lower where applied N and P were lower (below the recommended amount). As indicated in Table 1, treatments 2 and 6 are the same in terms of types of nutrients but due to the difference in the amount of N and P, significant yield difference was observed between them. Receiving the recommended amount of N and P, treatment 6 gave significantly higher grain yield than treatment 2. The blended fertilizer that contains balanced nutrients but lower N and P than the recommended amounts produced lower grain yield than the treatment contains only recommended amounts of N and P. Yield was significantly increased due to increasing only N to the recommended level in the balanced nutrients, whereas increasing only P to the recommended level did not significantly increase teff grain yield. Biomass and straw yields, and number of tillers also responded to the application of balanced nutrients. They also responded to increased application of N and P in the balanced nutrients; however, better response was seen to increased N to the level of recommended amount as compared to P. This could be because N contributes more to the performance of these parameters than to grain yield. The highest grain yield (1502 kg ha^{-1}), which was obtained with application of balanced nutrients containing the recommended amounts of N and P, has advantages of 26.54 and 39% as compared to the unbalanced nutrients (only recommended amounts of N and P) and the balanced nutrients with lower amounts of N and P, respectively. This indicates that it is very important to apply balanced nutrients with proper proportion for better production of teff in the experimental site. Applying either the recommended amount of N and P alone or balanced nutrients with lower amounts of N and P than the recommendation could not boost teff yield at Bensa resulting in lower yield than the regional average teff yield (CSA, 2016).

Economic analysis

According to the partial budget analysis (Table 2), the highest net benefit (20958.7 birr/ha) was obtained from the application of 64kgN+30kgP+25kgK+13kgS+2.4kgZn+1kgB/ha, whereas application of 46kgN+20kgP+16kgS+2.6kgZn/ha gave the lowest net benefit (18591.5 birr/ha). The result of the dominance analysis revealed that except 64 kg N + 30 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha and 64 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha the remaining were dominated by the alternatives with lower total cost that varied. The highest MRR (137.8%) (Table 3), which is well above the minimum acceptable rate of return (100%), shows a one birr investment on application of 64 kg N + 30 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha as compared to the use of 28 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha would yield a net extra benefit of 13.78 Birr. Besides**,** shifting from application of 28 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha to application of 64 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha has a marginal rate of return of 107.8% indicating that a one birr investment on application of 64 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha as compared to the use of 28 kg N + 18 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha would yield a net extra benefit of 10.78 Birr. Both yield and economic analysis revealed that application of 64 kg N + 30 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha with the indicated amounts are the best balance and proportion for teff production at Bensa.

Table 2. Partial budget, Marginal rate of return, and Dominance analysis of fertilizers for teff production at Bensa

Treatments	straw yield	Av. yield	Adj. yield	TCTV (ETB/ha)	Revenues (ETB/ha)	NB (ETB/ha)	MRR (%)
46kgN+20kgP+16kgS+2.6kgZn/ha	3.83	1243	1119.1	3082.82	21674.3	18591.5	
64 kgN + 30 kg P/ha(recommended amount of NP)	3.27	1187	1068.2	3174.26	20533.8	17359.6	D
28kgN+18kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	3.22	1081	973.17	3381.82	18803.8	15422	D
64kgN+20kgP+16kgS+2.6kgZn/ha	3.42	1281	1152.8	3538.29	22116.6	18578.4	D
64kgN+18kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	4.52	1365	1228.9	4166.6	23926.2	19759.6	
28kgN+30kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	3.52	1207	1086.7	4251.65	20969.3	16717.6	D
64kgN+30kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	4.14	1503	1352.3	5036.43	25995.2	20958.7	

Yield adjustment=10%, Field price of teff = 18/kg, MRR= marginal rate of return, MARR=100%, BF= blended fertilizer, Av.yield= average yield, Adj.yield=adjusted yield, TCTV= total cost that vary, NB=net benefit, D= dominated treatments, ETB=Ethiopian Birr

Table 3. Analysis of Partial budget and Marginal rate of return of fertilizers for teff production at Bensa

Fertilizers (kg/ha)	straw yield kg/ha	Av.yield kg/ha	Adj. yield kg/ha	TCTV (ETB/ha)	GFB (ETB/ha)	NB (ETB/ha)	MRR (%)
46kgN+20kgP+16kgS+2.6kgZn/ha	3.83	1243	1119.06	3082.82	21674.3	18591.52	
64kgN+18kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	4.52	1365	1228.86	4166.6	23926.2	19759.62	107.8
64kgN+30kgP+25kgK+13kgS+2.4kgZn+1kgB/ha	4.14	1503	1352.25	5036.43	25995.2	20958.73	137.8

GFB= gross field benefit

Conclusion and recommendation

This study clearly revealed that applying only N and P is not adequate for better teff production at Bensa calling for application of balanced nutrients. The blended fertilizer that contains balanced nutrients with recommended amounts of N and P produced significantly higher teff yield compared to the recommended N and P alone and the balanced nutrients with lower N and P. The economic analysis also depicted that applying the balanced nutrients with proper proportion of N and P could give the highest marginal rate of return. Therefore, application of 64 kg N + 30 kg P + 25 kg K+ 13 kg S + 2.4 kg Zn+ 1 kg B/ha is recommended for production of teff at Bensa.

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