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Evaluating the Effect of NPSB Fertilizers on Barley (*Hordeum vulgare* L.) Production and Productivity at Tocha Woreda, Southwest Ethiopia

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Abstract

Several blended fertilizers (BFs) were formulated and introduced but site and crop specific rate were not identified. Research was conducted in Tocha woreda to evaluate the rate of NPSB fertilizer to improve barley yield during the main cropping season of 2019 and 2020. The experiment consists of seven treatment, such as control(0), recommended NP (69 kg N and 20 kg P), NPSB: 18.9–37.7–6.95–0.1 (100 kg NPSB), NPSB: 41.9–37.7–6.95–0.1(100 kg NPSB + 50 kg Urea), NPSB: 62.85–56.55–10.425 –0.15 (150 kg NPSB + 75 kg Urea), NPSB: 83.8–75.4–13.9–0.2(200 kg NPSB + 100 kg Urea) and NPSB: 104.75–94.25–17.375–0.25 (250 kg NPSB + 125 kg Urea). Soil physiochemical properties of the experimental site were slightly acidic, moderate level of OC and total N, high level of exchangeable K and CEC, low level of available P, sulfur and boron and clay loam textural class. The significant effect of NPSB fertilizer was observed on barley yield and yield components at T6 which was 200 kg NPSB + 100 kg Urea and gave significantly higher yield with the highest net benefit (124752 ETB/ha) and acceptable MRR (3262.07%). Similarly, treatment 3 and 5 gave considerable net benefit with acceptable MRR of 1062 and 149%, respectively, but statistically non-significant and lower MRR when compared with T6 which gave optimally yielded. Based on economic analysis and statistical information T6 which 200 kg NPSB and 100 kg urea treatment was recommended as the best option for barley production for farmers at Tocha woreda southwest Ethiopia and areas with the same agro-ecology.

Keywords: Blended fertilizer, soil properties, barley productivity, south west Ethiopia

INTRODUCTION

Food barley (*Hordeum vulgare* L.) is cereal crop belongs to genus Hordeum in the tribe Triticeae of the family Poaceae. Barley is grown throughout the world at high concentration at both high altitude and temperate areas of tropics and subtropics. It has the great importance in social and food habits of Ethiopian people. It is one of the most economical important and stable food crops that vastly used and produced in highland Ethiopia and fifth important crop next to wheat, maize, teff, and sorghum in production and productivity [1].

Barley is a large commercial crop that produced for both industrial malt grain and cottage local beer and alcohol production. Also used as animal fodder as source of fermentable material for beer and certain distilled beverages, component of various health foods and used also in soup and brews, bread at various cultures [2]. It grains also used for preparing different food stuffs, such as injera, kolo, bread, and local drinks, such as beer, borde, and tela [3, 4] and its straw also useful for thatching roofs and bedding of house as well as animal feed during dry season [5].

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Many constraints hinder agricultural productivity in Ethiopia. The soil of Ethiopia has been subjected to severe degradation caused by different factor, such as manmade and natural [6]. Most of Ethiopian soils, especially in the highlands, are low in nutrient content due to erosion, leaching, and absence of nutrient recycling [7]. According to Abebe et al. (2022) [8], production of barley in Ethiopia falls under low-fertility soils, which is a bottleneck to sustainable agricultural production and productivity in Ethiopia [9]. Balanced fertilizer applications play an important role in crop production and maintain soil health in both economic and environmental considerations.

An imbalanced fertilizer uses results in low fertilizer use efficiency leading to less economic returns and a greater threat to the environment [10]. The key determining factor of yield was the amount of available plant nutrients that are found in soil or added to the soil from external sources of organic, mineral, or biological sources to maintain soil fertility and sustainable production [11]. ETHIOSIS reported that the coverage of blended fertilizer (BF) NPSB nearly reached about 86.4% at southern Ethiopia. Based on this information in Tocha woreda more than 50% NPSBCu and 20%–29% NPSB soils nutrient were deficient or suggested fertilizers [12].

A "*mehare*" season barley production of Dawuro zone was 769 ha land coverage and 11,940.47 quintal yield with average productivity of 15.53 quintals per hectare [1, 13]. This production of barley was lower than its potential of greater than 24 quintals per hectare in some research reports.

Multi-nutrient containing blend fertilizers were used in soil of Ethiopia at different areas to produce barley [12]. Using those fertilizers has great importance to ensure supply of most nutrients required by crops and it's admirable to determine rate and application fertilizers for different crops [14]. Therefore, this study was conducted to provide site and crop specific economically sound fertilizers rate and recommendation for barley production at Tocha district in south-west Ethiopia [15].

MATERIALS AND METHODOLOGY

Description of the Study Area

The study was Dawuro zone Tocha woreda in southwestern Ethiopia and conducted for two consecutive years during 2019–2020 main cropping seasons. The study site located in geo-reference to at latitude 7°54'24" N and longitude 38°22'02" E and elevation of 2661 m above sea level (Figure 1). Tocha woreda had three agro-ecological region: first, *Kola* agro-ecology ,which ranges from 500–1500 m above sea level and received about 522–1500 ml rainfall; second, *woyena dega* with altitudes of 1501–2500 m and received a rainfall of 1500–2000 ml; and third, *Dega* greater than 2500 m above sea level and get >2500 ml of rainfall annually.

METHODS AND MATERIAL

Experimental Design and Procedures

The research was conducted with experiment design of RCBD and had seven treatments with three replications and conducted for two consecutive years at two farmland. The experiment lay out with 4 × 4 m plot size and between plots and block spacing were 50 cm and 1 m, respectively. The space between rows was 20 cm and seeds were sown by drilling. The experiment had seven treatments T1:control (no fertilizers), T2 : recommended NP (69 kg N and 20 kg P per ha) , T3: 100 kg NPSB (18.9–37.7-6.95-0.1), T4: NPSB: 41.9-37.7-6.95-0.1 (100 kg NPSB + 50 kg Urea), (T5) NPSB: 62.85-56.55-10.425 -0.15 (150 kg NPSB + 75 kg Urea), (T6) NPSB: 83.8-75.4-13.9-0.2 (200 kg NPSB + 100 kg Urea) and (T7) NPSB: 104.75-94.25-17.375-0.25 (250 kg NPSB + 125 kg Urea). The fertilizers NPSB and TSP were applied at planting time and urea was side dressed in 45 days after planting for all treatment except T1. The N rate also applied by split, that is, one third at planting, raining two-third side dressed and food barley variety used for this experiment was BH-1307.

Soil Sampling and Analyses

Composite surface soil samples were collected from each experimental farm before planting during first year from 0–20 cm depth by soil auger nearly five spots at different place diagonal. These subsamples were thoroughly mixed, homogenized, air dried, grounded, and passed through a 2 mm sieve. The samples were analyzed for different physiochemical properties, such as soil texture, pH, available phosphorus, total nitrogen, organic carbon, sulfur, boron, exchangeable K^+, and cation exchange capacity (CEC) using respective analytical techniques and procedures outlined in [16]. Soil pH analyzed by soil to water suspension (1:2.5 ratio), organic carbon in wackily and blackly methods (Wackily and Blackly, 1934), available P in Olsen methods [17], sulfur and Boron in turbid metric methods and dilute HCl methods, CEC and K in extracting 1N ammonium acetate.

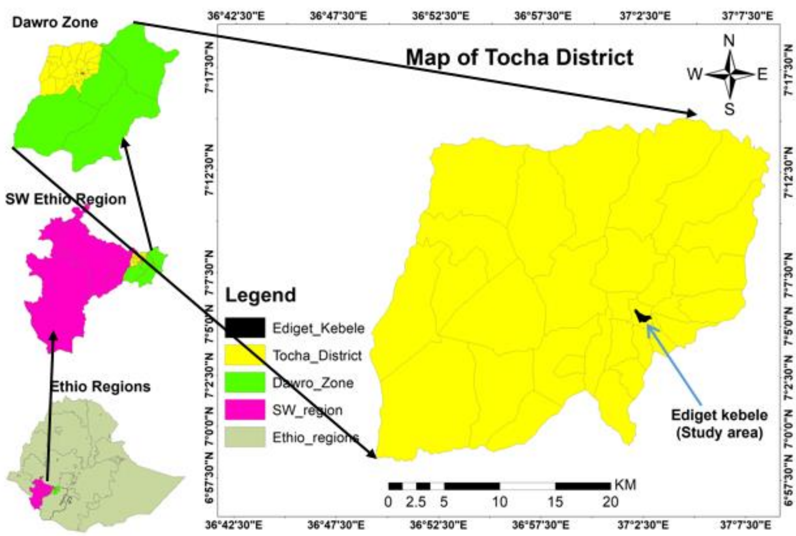

Figure 1. The study site map of Dawuro zone Tocha woreda in south-west Ethiopia.

Data Analysis

The collected data were subjected to statistical analysis. The analysis of variance (ANOVA) was carried out using SAS software version 9.2 programs [18]. The difference between treatment was compared by using LSD test at 95% level of significance when ANOVA shows significant difference. The economic analysis with partial budget, dominance, and marginal rate of blend fertilizers used for barley production to investigate economic feasibility analyzed by CIMMITY manual [3, 4].

RESULTS AND DISCUSSION

Physicochemical Properties of the Experimental Field Soil

The physicochemical analysis of composite soil sample was analyzed by standard analytical methods. The analysis of pH in soil to water suspension in 1:2.5 ratios indicates that soil of the experimental site was moderately acidic and satisfactory for most crops [19, 20]. The concentration of OC and TN was 3.96% and 0.18 % which was rated high according to [19] and that is adequate for crop production [21]. The concentration of available phosphorus (P) was analyzed by Olsen methods and medium according to Olsen analysis rating [17] and in line with ETHIOSIS soil map reported at 2017 [22]. The exchangeable potassium and CEC were analyzed by 1N ammonium acetate leachate and former were read in Flame photometer and later by keldjal distillation and titration. From the laboratory analysis report the result of potassium and CEC was 0.87 and 35.6 meq/100 g of soil. The amount of K and CEC was high according to [23] and [21], respectively. Available boron of study areas was 0.51 mg/kg, which was low according to ETHIOSIS soil because critical level for Ethiopian soil was 0.8 ppm and available sulfur was 13.4 mg/kg, which was also low for study site as report of ETHIOSIS soil map critical level, that is, classification of sulfur level <9 (very low), 10–20 (low), 20–80 (medium), and >80 (optimum) but the site sulfur level was 13.4 mg/kg, which shows it was under low ranges; so application of sulfur containing fertilizer was relevant for production barley at study site and low level sulfur was due to low organic carbon. It was also related to continuous cultivation, which result intensive mining of S from the soil [22, 24, 25]. The physical parameter which was particle size distribution and bulk density was analyzed for experimental site and former were analyzed by sodium hexa-meta phosphate or Calgon solution as dispersing agent and read by hydrometer. The result shows that the site had 39% sand, 30% clay, and 31% silt and site had sandy loam textural class on textural triangle and bulk density analyzed done by cylindrical shaped core sampler and shows compactness of soil and result of BD was 1.4 g/cm^3 which greater than 1.3 implies the soil had medium compacted and higher sand percentage of soil (Table 1).

Table 1. Physicochemical properties of soil at study areas.

pH	BD g/cm^3	% OC	P ppm	% TN	K meq/100 g	B mg/kg	S-SO_4 mg/kg	CEC meq/100g	% Sand	% Clay	% Silt	Text. Class
5.65	1.43	3.96	7.34	0.18	0.87	0.51	13.4	35.6	39	30	31	Clay loam

Note: BD: Bulk density; CEC: Cation exchange capacity; meq: mill equivalent.

Effects of NPSB on the Yield of Barley at Tocha District

The results of ANOVA also revealed that the application different BF rate had significant influence on plant height, number of tillers, above ground biomass, and grain yield of barley but the effect was not observed in the spike length statistically (Table 2). Maximum numbers of tillers (4.32), above ground biomass (11574.53 kg/ha), and grain yield (4368.83 kg/ha) were obtained from the application of NPSB with the ratio of 83.8–75.4-13.9-0.2 (200 kg/ha NPSB + 100 kg/ha of urea); whereas maximum plant height (95.72 cm) and spike length (6.40 cm) were observed from the application of recommended N and P. According to [26], the application of N, P, S, and B to soil increases the crop agronomic data, such as number of tillers, plant height, spike length, and number of kernels. All parameters except grain yield were statistically not significant when BF's effect compared with the effect of Recommended NP. While grain yield, among the treatments, 200 kg/ha NPSB + 100 kg/ha of urea and 250 kg/ha NPSB + 125 kg/ha of urea produced higher yield when compared to RNP with the yield advantage of 29.75% and 20.67%, respectively. The former study of [27] implies that positive and high response of BF is an indication of soils deficient on the nutrients like S, B, and Zn and also in line with study of [28], in which grain yield increase with applying of both macro and micro nutrients and current study was agreed with former studies stated above. The current study was in line with former study of south Ethiopia because the biomass, spike length, number of branches, and grain was influenced by NPSB fertilizers and yield was statistical significantly across treatment in different rate [20, 29].

Table 2. Effects of fertilizer rate on the yield of barley in Tocha zone, southern Ethiopia.

No.	Treatment	pH (cm)	NT	SL (cm)	BM (kg/ha)	GY (kg/ha)
1.	Control/no fertilizer	82.32^{b}	2.82^{d}	5.81	5918.3^{c}	1788.7^{d}
2.	RNP (69-20)	95.72^{a}	4^{abc}	6.4	8471.4^{abc}	3073.7^{bc}
3.	NPSB: 18.9-37.7-6.95-0.1	88.12^{ab}	3.2^{bcd}	5.77	7618.3^{bc}	2601.5^{cd}
4.	NPSB: 41.9-37.7-6.95-0.1	88.12^{ab}	3.04^{cd}	5.99	7078.9^{bc}	2573.8^{cd}
5.	NPSB: 62.85-56.55-10.425 -0.15	92.98^{a}	3.76^{abcd}	6.15	9330.8^{ab}	3401.7^{bc}
6.	NPSB: 83.8-75.4-13.9-0.2	93.62^{a}	4.32^{a}	6.12	11574.5^{a}	4368.8^{a}
7.	NPSB: 104.75-94.25-17.375-0.25	91.16^{a}	4.22^{ab}	5.87	10378.9^{ab}	3873.4^{ab}
LSD ($p < 0.05$)		8.77	1.05	NS	3313.20	856.17
CV (%)		7.11	21.86	11.19	28.61	18.89

Note: RNP: Recommended N and P; PH: plant height; NT: number of tillers; SL: spike length; BM: biomass; GY: grain yield; NS: statistically non-significant; CV = coefficient of variance.

Economic Analysis

The economic analysis in Table 3 indicates treatment 2, 4, and 7 were of higher benefit with minimum variable cost. The T3 had a higher net profit and the lowest variable cost than T4; T5 had also a lower variable cost and higher net profit compared to T2. From economic analysis Table 4, T3, T5, and T6 were potential options for farmers to use and economical ones. Based on partial budget analysis T6, which had higher net profit compared to T3 and T5 with marginal rate of return 3262.07%. The marginal rate of return for T3 and 5 was 1021.37% and 1469.0%, which means investing 1 ETB in the producer can get more than 100%, which was higher than minimum acceptable rate of returns, that is, 100%, so both treatment 3 and 5 were given extra investment. But both T3 and

T5 were statistically non-significant relative to T6, which give optimum yield of barley, therefore rejected from potential option [30]. Finally, T6 were the only option for producer of barley at Tocha woreda, south-west Ethiopia.

Table 3. Economic (partial budget and dominance) analysis of fertilizers on maize.

Treatment	NPSB (kg/ha)	Urea (kg/ha)	TSP (kg/ha)	Adjusted Yield (kg/ha)	TVC (ETB)	GFB (ETB)	NB (ETB)	Dominancy
1.	0	0	0	1788.71	0	53700	53700	
3.	100	0	0	2601.52	2167	78000	75833	
4.	100	50	0	2573.81	3174	77100	73926	D
5.	150	75	0	3401.67	4761	102000	97239	
2.	0	150	100	3073.69	5188	92100	86912	D
6.	200	100	0	4368.83	6348	131100	124752	
7.	250	125	0	3873.37	7935	116100	108165	D

Note: Yield adjustment: 10%; field price of barley: 30; TSP: triple super phosphate; TVC: total variable cost; GFB: gross field benefit; NB: net benefit; D: dominated; ETB: Ethiopian birr.

Table 4. Economic (partial budget and marginal rate of return) analysis of fertilizers on maize.

Treatment		Adjusted Yield (kg/ha)	TVC (ETB)	GFB (ETB)	NB (ETB)	% MRR
1.	No fertilizer	1788.71	0	53700	53700	
3.	NPSB: 18.9-37.7-6.95-0.1	2601.52	2167	78000	75833	1021.37
5.	NPSB: 62.85-56.55-10.425 -0.15	3401.67	4761	102000	97239	1469.00
6.	NPSB: 83.8-75.4-13.9-0.2	4368.83	6348	131100	124752	3262.07

Note: Yield adjustment: 10%; field price of barley: 30; TVC: total variable cost; GFB: gross field benefit; NB: net benefit; ETB: Ethiopian birr.

CONCLUSION AND RECOMMENDATION

Many constraints hinder agricultural productivity, such as deletion of soil fertility, inappropriate and imbalance use and application of fertilizer, low-nutrient availability of soil due to erosion, and leaching reduce yield of cereal crop, including barley in Africa and Ethiopia.

The output of this study shows that applying soil deficient nutrient, such as N, P, S, and B (NPSB) fertilizers with ratio of 83.8, 75.4, 13.9, 0.2 (200 kg NPSB+100 kg Urea, T6) gave significantly optimum yield compared (4368.83 kg/ha) to other treatments and also the highest net benefit was obtained with acceptable marginal rate of return (3262.07%) and potential option for barley producers at study site, which is greater than minimum acceptable marginal rate of return (100%). Therefore, study recommend 200 kg NPSB + 100 kg urea was best option for barley producers at Tocha district and area with same agro-ecology based on yield response and economic analysis at south-west Ethiopia.

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