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Evaluating NPSZnB Blended Fertilizers Response of Malt Barley (*Hordeum distichum* L.) Grown in the Vertisols Areas of South Tigray, Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Both AW and BE contributed to the data collection, data management, analysis, and preparation of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Study on the effect of different bended fertilizers level on malt barley was conducted in 2018- 2019 at Ofla, Enda-Mehoni and Emba-Alaje districts of South Tigray, Ethiopia with the objective of determining economically feasible rate of NPSZnB blended fertilization for malt barley production. The experiment was laid out in randomized complete block design (RCBD) with seven level of blended fertilizer (0, 50, 100, 150, 200, 250 and 300 kg NPSZnB ha^{-1}) and replicated three times. Grain yield malt barley was significantly (P=.05) affected by the application of NPSZnB blended fertilizers. Significantly higher malt Barley grain yields of (3.67 and 4.17 t ha^{-1}) with higher economic return (69,811.68 and 82,635.89 Birr ha^{-1}) and acceptable marginal rate of returns (1,234.01 and

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90.01%) were recorded from the application of 150 kg NPSZnB ha^{-1} in Adi-golo and Mekan districts, respectively. More over higher grain yield with higher economic return (68,033.23 Birr ha-^{1}) with acceptable marginal rate of return (669.86%) was obtained at Atsela districts from the fertilization of 100 kg of NPSZnB ha^{-1} blended fertilizer. Hence, application of 150 kg NPSZnBha-^{1} blended fertilizer is agronomical and economical optimum level for Adi-golo and Mekan districts and 100 kg NPSZnB ha-1 of blended fertilizer for Atsela and other similar agro-ecologies and soil conditions. Even if there is significance effect of blended fertilizers on grain yield of malt barley, the highest yield obtained is not the potential of the variety, hence integration of blended and nitrogen fertilizer is further research directions to boost the grain yield with brewing quality attributes in malt barley.

Keywords: Malt barley; blended fertilizer; grain yield; economic return.

1. INTRODUCTION

Barley (*Hordeum vulgar L.)* is an important cereal crop grown worldwide for food, animal feed and a raw material for the malting process to produce beer or other alcoholic beverages [1,2]. In Ethiopia, there is substantial chance for the production of malting barley and can be one of the main sources of revenue for farmers as growing demand for malt resulting the expansion of breweries factories [3].

The profitability of malt barley is influenced basically by the kernel yield, which in turn be governed by factors like variety, farming practices, soil and macroclimate [4]. Though, grain yield of malt barley is growing in the past decades barley productivity in Ethiopia is around 2.50 t ha^{-1} [5], which is lower than world average barley productivity (2.95 t ha^{-1}), below yields in the better performing African countries of Kenya (3.26 t ha^{-1}) and South Africa (2.93 t ha^{-1}), and below yields in the top world performing countries, like France, Germany and Netherlands (over 6.0 t ha^{-1} [6]. Agriculture in Ethiopia is very low productivity, mostly due to low soil fertility and luck of effective, sustainably and sites-specific soil fertilization practices. Fertilizer application on Barley is the lower than among all cereal crops, which is only 48.3% of the total area covered by Barley related to Tef, Wheat, and Corn fertilization on 59.7%, 69.1% and 56.3% of their overall land area correspondingly [7]. In addition, in the past decades, Agriculture in Ethiopia depended only on imported urea and di-ammonium phosphate fertilizers, which are source of nitrogen and phosphorus though utmost Ethiopian soils deficiency other macro- and micro-nutrients [7]. This could lead to low nutrient uptake efficiency of crops because of low accessibility or absence of synchrony of maximum growth of crops with sufficient accessibility of the nutrients in the soil. Based on the EthioiSIS soil catalog, in addition to the macronutrients, due to extensive farming, some of the micronutrients like Zn, B, and Cu are depleted from the soil in the main crop producing part of Ethiopia [7].

One most important weakness to raise fertilizer use efficacy in the country has been absence of evidence on fertility eminence of the cultivated land. Currently, the government and a national land resource have recognized the problem and soil fertility mapping work is carry out by the Ethiopian Soil Information System (EthioSIS)). This initiative has been conducted throughout the country to assess the soil fertility status accordingly that fertilizer recommendations can be based on soil test results.

Many research findings have reported that nutrients like nitrogen, Phosphorus, Potassium, Sulfur, Iron, Zink, Boron and Copper levels are becoming depleted and insufficiency indicators are being detected on main crops in many areas of the country [7]. Macronutrients and micronutrients are main significance in Ethiopian agricultural system but, because of unawareness of the farmers about significance of fertilizing micronutrients and inaccessibility, the soils are becoming deficient in micronutrients. Other research outcomes indicate that the uses of balanced fertilizers have encouraging effect in growth and development of crops, which resulted in enhanced quality and quantity of the agricultural produce.

High fertilizer responsive crop varieties express their yield potential when micronutrients applied alongside with nitrogen and phosphorus fertilizers [8]. Micronutrients increased the wheat yields over control when applied in blend with N, P, S nutrients. Site specific soil test based application of fertilizer specifically those comprising sulfur, boron, Zink and other nutrients is suggested in avoiding complications produced as a result of nutrient deficient soils [7].

Consequently, application of blended fertilizers comprising together macro and micronutrients, based on the site-specific soil fertility mapping is supposed as paramount solutions for such production limitations. Though nutrient content of the fertilizer that suits the needs and productivity of the crops in most part of Ethiopia, particularly South Tigray, farmers have limited information on the influence of blended fertilizer kinds and levels excluding only urea and DAP. However, new blended fertilizer such as NPSZnB (13.0 N +26.1 P_2O_5 + 5.6S+ 1.72Zn + 0.51B) is currently being used by the farmers in the study area based on the soil fertility map of the area [7].

However, little information is known and limited recommendations occur about effect of NPSZnB blended fertilizer on malt barley yield in Ethiopia in overall and the Tigray highlands in specific. Hence, the aim of this study was to evaluate the effects of NPSZnB blended fertilizer rates on the productivity of malt barley in the vertisol areas of southern high lands of Tigray, Ethiopia.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was conducted in 2018 & 2019 cropping season at Ofla (Adi-golo) Enda-Mehoni (Mekan) and Emba-Alaje (Atsela) areas of south Tigray, Ethiopia. Adi-golo kebelle is one of the kebelle of Ofla woreda in southern zone of Tigray. It is located on the latitude of 12°32’15" N, and longitude 39°30'4" E and lies at an altitude of 2450 meters above sea level (Fig. 1). The long-term (1997-2019) mean annual rainfall was 996 mm, while the mean annual rainfall for the study periods of 2018 and 2019 was 1070.3 mm and 949.4 mm respectively. The maximum and minimum daily temperatures were 22.3°C and 7.8°C, respectively. Mekan kebelle is located in southern zone of Tigray in Enda-Mehoni woreda. It is located on the geographic coordinates of 12°44'31” N, 39°31'17"E N and lies at an altitude of 2470 m.a.s.l (Fig. 1). The long-term (1999-2019) mean annual rainfall was 712mm and the rainfall for the study periods of 2018 and 2019 was 837.8 mm and 662.6 mm respectively with maximum and minimum daily temperatures of 22.4°C and 10.2°C, respectively. Atsela kebelle is located in southern zone of Tigray in Emba-Alaje woreda. It located on the on the geographic coordinates of 39°31'37"E, 12°55'21"N, with altitude of 2490 meters above sea level. The long term (2000-2019) mean annual rainfall was 602 mm, with the mean maximum and minimum daily temperatures of 22.1°C and 10.1°C respectively.

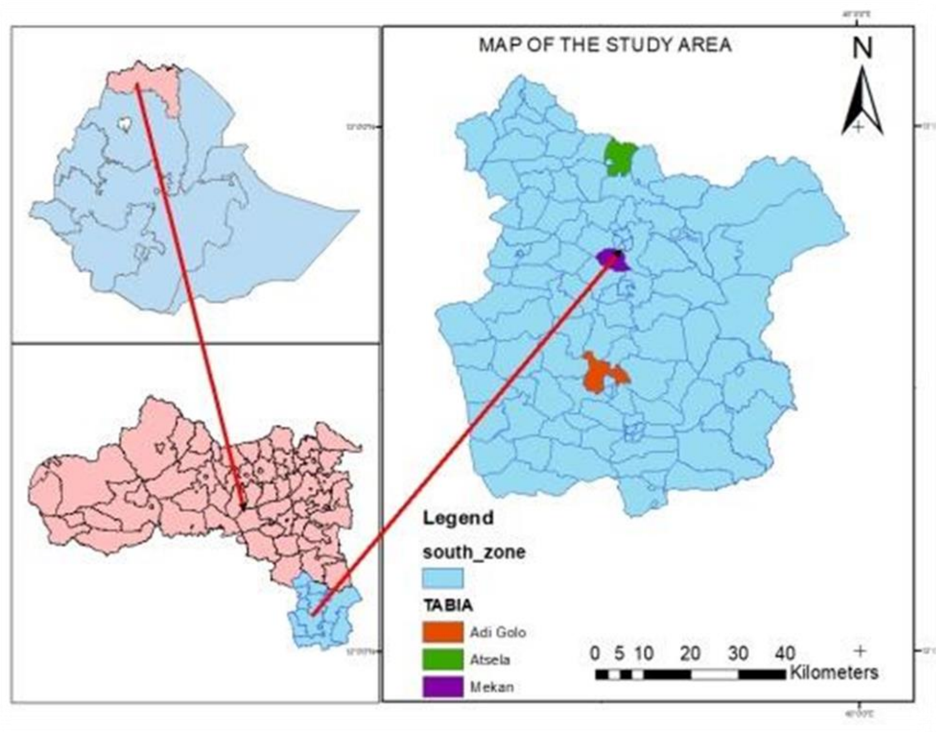

Fig. 1. Map of study locations

2.2 Experimental Design, Treatment and Procedures

The field experiment comprises seven different rates of NPSZnB blended fertilizers (0, 50, 100, 150, 200, 250, & 300 kg ha^{-1}). The treatments were laid down in a randomized complete block design replications three times. Nitrogen fertilizer was applied at two splits, one third at planting and two third after forty days of planting by adjusting nitrogen level in the blended fertilizer. Improved malt barley variety known EH1847 was panted by drilling seeds in rows using manual row maker at seed rate of 150 kg $ha^{-1}$and row spacing of 20 cm.

2.3 Data Collection

Grain yield: Grain yield (kg $plot^{-1}$) was collected from each experimental plot with hand sickle by exclusive of the border rows, adjusting to 12.5% moisture level, and then converted to hectare (ha) basis.

Soil data: Five composite disturbed soil samples were collected randomly at the 0–20 cm soil depth from the entire experimental area in the start of the study 2018. Each sample was mixed methodically in a bag & a sub-sample was taken for investigation following regular processes of [9]. The samples were dried, passed through 2 mm sieve and analyzed for texture, Soil organic carbon, cation exchange capacity, pH, total nitrogen and available phosphorus using standard methods of physico-chemical analysis. The results of soil analysis are presented in section 3.1.

2.4 Data Analysis

The analyses of variance (ANOVA) for the studied variables were computed using technique of R software version following the procedures for randomized complete block design. The data were analyzed using R programming software (version 4.0.0) with the updated statistical package R Core Team (2020).

2.5 Partial Budget Analysis

Economic analysis was used to estimate the economic profitability of blended fertilizer levels based on the kernel and straw yields of the crop. In this study, we select the most economically acceptable NPSZnB treatments by calculating the particular prices and profits based on market prices for 2019 [10]. It is common that investigational yields are greater than the yields that farmers can expect using the same level of treatments [11]. Thus, in the economic computation, the straw and grain yields were adjusted to 90% of the actual yield attained from the trial plots to exemplify a higher accurate yield in farmers' fields [11]. The net benefit was calculated as the difference between the gross benefit and the total varying cost. The marginal rate of return was computed by dividing the change in net benefit by the change in variable cost. The marginal rates of returns were computed after dominance analysis [11] to select the treatments that are important to farmers in terms of return. A treatment is dominated when rise in costs does not lead to rise in net benefits. It is dominated because there is at least one more treatments of less or equal cost that contributed higher benefits. To perform the partial budget analysis, the treatments were organized according to an increasing order of total varying variable costs and compared whether increasing costs are followed by increase in net benefits.

Blended fertilizer & labor costs were determined according to their prices in the specific locations. The costs for the NPSZnB blended and urea fertilizers were 15.81 and 16.5 Birr kg^{-1} and the market price of grain & straw yield of malt Barley were calculated according to 2019 market prices and prices of 30 and 1.5 Birr kg^{-1} grain & straw yield of malt Barley respectively.

3. RESULTS AND DISCUSSION

3.1 Soil Physical and Chemical Properties of the Study sites

The results **soil physical and chemical properties of the study sites**, as presented in Table 1. Accordingly, soil texture indicates that the particle size distributions of the surface soils of the research districts were dominantly clay soil (above 50 %) except at Adi-golo (40 %). The average pH values of the research districts were in the range of slightly neutral soil reaction [12]. The soil organic matter (SOM) contents of the study areas were in the ranges of 1.24 to 1.99% therefore, these values categorized in the low to moderate ranges according to Tekalign [12]. Total N of the experimental districts was in the ranges of 0.101 to 0.17% & considered as low [13]. Likewise, according to P rating established by [10], the available phosphorus status of the soil of the study sites is categorized in the medium phosphorus status. This illustration the low level of fertility status of the soils of experimental districts because of prolonged cereal based farming, absence of application organic materials soils by mulching or crop residues retention & frequent tillage. Mono cropping crop cultivation and unbalanced fertilization has been the most important reasons of soil fertility decline [14].

3.2 Grain Yield

As presented in Table 2 grain yield of malt barley indicated significantly (P =.05) affected by the application of different levels of NPSZnB blended fertilizers at Adi-golo, Mekan and Atsela areas. Significantly, more malt Barley grain yield of 3.668 t ha^{-1} was attained from fertilization of 150kg NPSZnB ha^{-1} blended fertilizer at Adi-golo study site. Nevertheless, there were not statistically significant differences (P =.05) with the malt barley grain yields 3.406, 3.338 & 3.233 t ha^{-1}respectively obtained from the application of 200, 250 and 300 kg NPSZnB ha^{-1} blended fertilizer levels respectively. While the least malt Barley, grain yields of 1.754 t ha^{-1} was attained from the no fertilized plot.

At Mekan testing site, the over year combined grain yield shows that the higher malt barley grain yields of 4.301 t/ha was recorded from fertilization of 150kg NPSZnB ha^{-1} blended fertilizer however; statistically there is no also significance different (P =.05) on grain yield of malt barley with the fertilizing of 200 and 250 kg NPSZnB ha^{-1} blended fertilizer application (Table 2). At Atsela experimental site the combined grain yield of malt barley over the years shows that the higher grain yield of 3.795 t/ha was gained from the fertilization of 100kg NPSZnB ha^{-1} blended fertilizer. However statistically, there is no also significance different on grain yield of malt barley with the fertilizer treatments of 150kg, 200kg and 250 kg NPSZnB ha^{-1}applications. While the least malt barley grain yield of 1.75 t/ha was recorded from, the none fertilized plot.

Table 1. Soil Physical and Chemical Properties of the experimental districts

Soil property	Study districts		
	Adi-golo	**Atsela**	**Mekan**
pH(1:2.5 H2O)	6.74	7.55	6.87
Av.P(mg /kg soil)	11.00	47.40	35.10
TN (%)	0.101	0.17	0.15
OC (%)	1.99	1.36	1.24
EC(ds/m)	0.09	0.16	0.09
CEC (cmol(+)/kg of soil)	41.67	40.28	48.85
Exch k^+(cmol(+)/kg of soil)	0.20	1.34	0.55
Exch Na^+(cmol(+)/kg of soil)	0.66	1.28	0.96
Exch Ca^{2+}(cmol(+)/kg of soil)	25.56	27.03	24.17
Exch Mg^{+2}(cmol(+)/kg of soil)	8.52	9,59	8.9
Silt (%)	15	24.16	14.84
Sand (%)	25	25.31	30.05
Clay (%)	40	50.53	55.11
Textural class	clay	clay	clay

Exch is Exchangable

Table 2. Combined mean grain yield of malt barley

NPSZnB rate (kg ha^{-1})	Mean grain yield (t ha^{-1}) in 2018 & 2019 cropping season		
	Adi-Golo	**Mekan**	**Atsela**
0	1.754d	2.542e	1.924d
50	2.521c	3.281d	3.022c
100	2.812bc	4.179b	3.516ab
150	3.668a	4.301ab	3.795a
200	3.406a	4.53a	3.691a
250	3.338a	4.214ab	3.581ab
300	3.233a	3.634c	3.337bc
LSD (5%)	0.314	0.18	0.304
CV %	9	4.7	5.5

Table 3. Partial budget analysis

Study sites	NPSZnB rate (kg ha^{-1})	GY (t ha^{-1})	Adj.GY (t ha^{-1})	TVC (birr ha^{-1})	TR (birr ha^{-1})	NB (birr ha^{-1})	MRR (%)
	0	1.92	1.73	0.0	38979.18	38979.18	
	50	3.02	2.72	1900.0	61,224.06	59324.06	1,070.78
Atsela	100	3.52	3.16	3200.0	71232.23	68032.23	669.86
	150	3.80	3.42	4500.0	76,884.61	72384.61	334.80
	200	3.17	2.86	5800.0	64303.49	58503.49	D
	250	3.41	3.07	7100.0	69165.76	62065.76	274.02
	300	3.71	3.33	8400.0	75061.26	66661.26	353.50
Adigolo	0	1.754	1.58	0.0	35535.08	35535.08	
	50	2.521	2.27	1900.0	51074.07	49174.07	717.84
	100	2.812	2.53	3200.0	56969.57	53769.57	353.3
	150	3.668	3.30	4500.0	74311.66	69811.66	1,234.01
	200	3.406	3.07	5800.0	69003.69	63203.69	D
	250	3.338	3.00	7100.0	67626.04	60526.04	D
	300	3.233	2.91	8400.0	65498.80	57098.80	D
Mekan	0	2.542	2.29	0.0	51499.52	51499.52	
	50	3.281	2.95	1900.0	66471.26	64571.26	687.99
	100	4.179	3.76	3200.0	84664.24	81464.24	1299.46
	150	4.301	3.87	4500.0	87135.89	82635.89	90.13
	200	4.53	4.08	5800.0	91775.31	85975.31	256.88
	250	4.214	3.79	7100.0	85373.32	78273.32	D
	300	3.634	3.27	8400.0	73622.84	65222.84	D

Where: GY=Grain yield, Adj= Adjusted Grain yield, GY=TVC = Total variable cost, NB = Net benefit, TR = Total Revenue, MRR = Marginal rate of return, D=Dominance

In line to this study research results in southern Ethiopia indicate that fertilization of 200 kg/ ha, NPSB blended fertilizer in food barley gave 70.4% and 68.9% increase in grain yield and economic return compared to the none fertilized [15]. Other research reports indicate that maximum grain and biomass yield of 6.8 and 13.01 t ha^{-1} respectively were obtained at of Arsi district of Oromiya region state from the fertilization of 250 kg/ha NPSZnB blended + 150 kg/ha urea fertilizers [16]. 20.2 and 26.9% respectively with the fertilization of NPSKB fertilizer at south Wollo, Ethiopia [17] improved biomass and grain yields.

Generally at Adi-golo & Atsela experimental sites grain yield of malt increase with increasing level of NPSZnB fertilizer (0 150 kg ha^{-1}) fertilization to certain level and grain yield show declining trend in maximum application of NPSZnB fertilizer (200-300kg ha^{-1}). Balanced application of fertilization is crucial to sustainable crop cultivation & maintenance of soil fertility and economic thoughtfulness, nevertheless an imbalanced nutrient fertilization results in low nutrient use efficacy which leading to less economic revenues and a more risk to the environment [18].

3.3 Partial Budget Analysis

In a partial budget analysis, it is expected that agriculturalists require a minimal rate of return of 100% (CIMMYT, 1988), demonstrating an increase in net return of at least 1 Birr for each one birr investment, to be adequately inspired to accept a new agricultural technologies. Every shift in investment of balanced fertilization from the lower nominated treatments to higher lead to more than 100% returns. The partial budget analysis indicated the maximum net benefits (72,384.61, 69,811.66 and 85,975.31 birr ha^{-1} from Atsela, Adigolo and Mekan areas respectively) were obtained from the fertilization of 150kg, 150kg and 200 kg NPSZnB ha^{-1} blended fertilizer levels. Next to the control, the application of 50 kg/ha NPSZnB blended fertilizer level gave the lowest net benefits at all locations (Table 3). Both on the marginal rate of return & the net benefit govern economically viable options of blended fertilizer.

With blende fertilizer application of 100 &150 kg, NPSZnB ha^{-1} the Marginal rate of returns (MRRs) were 669.86 and 334.8%, respectively for Atsela area. In Mekan areas, MMRs with blended fertilization of 50, 100,150 & 200 kg NPSZnB ha^{-1} were 687.99 and 1299.46, 90.13 and 256.8 % respectively. In Ad-golo experimental site, the MRRs with blended fertilizer application of 50,100 & 150 kg NPSZnB ha^{-1} were 717.84, 353.3, 92.5 and 1234.01% respectively. The farmers in Atsela study site would thus get an additional birr 10.7, 6.69 or 3.34 per one-birr investment from 50,100 and 150 kg NPSZnB ha^{-1} blended fertilizer, respectively. Birr 7.17, 3.53 & 12.34 in Adigolo and birr 6.89, 12.99 & 9.01 in Mekan from fertilization of 50kg, 100kg and 150 kg NPSZnB ha^{-1} blended fertilizer respectively. Economically feasible preferences are determined by combination of the MRRS, the NBs. Based on that, application of 100 kg NPSZnB ha−1 blended fertilizer for Adigolo and 150 kg NPSZnB ha^{-1} for Atsela, and Mekan areas respectively are economically feasible & hence recommended for practice by farmers of the study districts.

Sensitivity analysis was also performed with the hypothesis of the probable increase of input costs that can fluctuate over time. The results shown that the MRRs were still in additional of 100% demanding the same recommendations of 150 and 100 kg NPSZnB ha^{-1} could still work for the future would blended fertilizer cost increase? In instance, if the price of the varying costs rise by at a minimum 30% with in the coming three years, farmers who make the decision to produce malting barley with fertilizations of NPSZnB blended fertilizer at a rate of 150 kg ha^{-1} for Mekan and Adigolo and 100 kg ha^{-1} for Atsela areas respectively, potentially could earn an additional return for every Birr 1.0 investment.

4. CONCLUSIONS AND RECOMMENDATIONS

Declining of soil fertility, incorrect and imbalanced fertilization in addition to different blended fertilizer are furthermost reasons that decreases the production of cereal crops as well as malt barley in the study areas in specific and in Tigray region in general. For that reason, the research was conducted to investigate the influence of blended fertilizer levels on enhancing the productivity of malt barley at South Tigray districts, Ethiopia. Thus the current experiment indicated that application of different NPSZnB blended fertilizer levels were significantly (P =.05) affected grain yield of malt Barley at Adi-golo, Atsela and Mekan sites of Ofla, Emba-Alaje and Enda-Mehoni Woredas Tigray region respectively. Application of 150kg NPSZnB ha^{-1}blended fertilizer have all-encompassing and encouraging influence yield of malt barley productivity and reaches agronomical and economically optimum for malt barley production in the Adi-golo and Mekan experimental sites respectively &100 kg NPSZnB ha^{-1} at Atsela districts. Even if there is significance influence of blended fertilizers level on the grain yield of malt barley, the maximum grain yield obtained is not the potential of the variety, hence integration of blended and nitrogen fertilizer is further research directions to boost the grain yield with brewing quality attributes in malt barley.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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