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Response of Potato Yield (*Solanum tuberosum* L.) To Boron Blended Mineral Fertilizer Levels on Chromic Luvisols of Southern Highland Ethiopia

Melkamu Hordofa Sigaye*, Kidist Kebede, Ribika Mekuria

Ethiopian Institute of Agricultural Research Institute, Addis Ababa, Ethiopia

ABSTRACT

The drive for higher agricultural production without the balanced use of fertilizers created problems of soil fertility exhaustion. Inorganic fertilizers have been the important tools to overcome soil fertility problems and also responsible for a large part of the food production increases. The study was conducted at Bule, Gedio Ethiopia, and aimed to determine the optimum level of NPS-B and by supplementing N from urea rates for maximum yield of bread wheat production and to determine the economically optimum level of NPSB and by supplementing N from urea fertilizer. The treatments were: (100 kg ha^{-1} NPSB + 150 kg ha^{-1} Urea), (150 kg ha^{-1} NPSB+150 kg ha^{-1} Urea), (200 kg ha^{-1} NPS+150 kg ha^{-1} Urea), (250 kg ha^{-1} NPS+150 kg ha^{-1} Urea), (100 kg ha^{-1} NPSB + 250 kg ha^{-1} Urea), (150 kg ha^{-1} NPS + 250 kg ha^{-1} Urea), (200 kg ha^{-1} NPSB + 250 kg ha^{-1} Urea), (250 kg ha^{-1} NPBS + 250 kg ha^{-1} Urea), (100 kg ha^{-1} NPSB + 350 kg ha^{-1} Urea), (150 kg ha^{-1} NPSB + 350 kg ha^{-1} Urea), (200 kg ha^{-1} NPSB + 350 kg ha^{-1} Urea), (250 kg ha^{-1} NPSB + 350 kg ha^{-1} Urea), control and R NP (69N 46 P2O5). The treatments were arranged in a randomized complete block design and replicated three times. The result showed that maximum marketable tuber yield of (37.8 tone ha^{-1}) and unmarketable tuber yield (3.4 tone ha^{-1}) and total maximum tuber yield (41.1 tone ha^{-1}) were obtained from the application of 250 kg ha^{-1} of NPSB and 350 kg ha^{-1}. Application of 250 kg ha^{-1} of NPSB and 350 kg ha^{-1} of Urea fertilizers were superior in marketable tuber yield by 31.9% and 75.4% from recommended NP and control or unfertilized plot. The economic analysis revealed that the highest net benefit of 1042543.0 ETB ha^{-1} with marginal rate of return (MRR) of 273.0% was obtained in response to the application of 200 kg ha^{-1} of blended NPSB with 250 kg ha^{-1} of Urea. However, the lowest net benefit was obtained from an unfertilized or control plot. Therefore, applications of 250 kg ha^{-1} NPSB of blended plus 350 kg ha^{-1} of urea is economically advisable for farmers in the Bule districts Gedio, of southern Ethiopia and areas with similar agro-ecological and soil conditions for better potato production;

Keywords: Marketable yield; Potato; NPS-B blended fertilizers

INTRODUCTION

In Ethiopia, Potato (*Solanum tuberosum L.)* is one of the most important food crops and ranks first in volume of production and consumption among root and tuber crops of cassava, sweet potato, and yam [1,2]. Potato is grown in wider environmental conditions and, covering a total area of about 0.18 million hectares from which 1.62 million ton is harvested. And about 70% of the cultivated agricultural land of Ethiopia is suitable for potato production. Despite high potential production environments and marked growth, the national average potato yield in a farmer's field in Ethiopia is only 11.1 t ha^{-1}, which is lower than the experimental yields of over 38 t ha^{-1}, which is very low compared to the world average of 17.6 t ha^{-1} [1].

The decline in soil fertility driven by high rates of soil erosion (estimate 130 t ha^{-1} for cultivated fields), suboptimal fertilizer application rate, nutrient imbalance, depletion of soil organic matter and soil nutrients, soil erosion, highly variable rainfall, low-input farming practices are and limited access to improved varieties are among the major limiting factors claimed for low crop productivity in Ethiopia [3]. Similarly, [4] Low actual yield of potato in Ethiopia is related to different factors, such as poor soil fertility (for example, low level of organic matter and /or low pH, binding of phosphorus, and not mineralizing nitrate), and sub-optimal fertilizer application rates are most determining factors. Hailu *et al.*, [3] reported that the application of the low and unbalanced fertilizer together with poor soil fertility management is presented

***Correspondence to:** Melkamu Hordofa Sigaye, Ethiopian Institute of Agricultural Research Institute, Addis Ababa, Ethiopia, Tel: +251116454434; E-mail: hordofa.mel@gmail.com

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as the major causes for low agricultural productivity in Ethiopia. Such low levels of potato yield are widely believed to be due to low soil fertility caused by low, unbalanced fertilizer application and poor agronomic practices [5]. Under such conditions, the application of multi-nutrient blended fertilizers is acknowledged for being able to enhance productivity and nutrient use efficiency of crops and reduces nutrients losses to the environment.

Potato is a high-yielding and exhaustive crop and is affected by nutrient availability, thus, several researchers on fertilizers' application have received much attention worldwide [6,7]. Phosphorus application increases the tuber yield [8] and tuber number while inadequate nitrogen application leads to poor potato yield [9]. Similarly, [10] report that adequate nitrogen and phosphorous nutrition enhance many aspects of plant physiology, including the fundamental processes of photosynthesis, root growth particularly the development of lateral roots and fibrous rootlets as well as the uptake of other nutrients. Sulfur also ranks equal to nitrogen for optimizing crop yield and quality [11]. The crop growth is greatly influenced by a wide range of nutrients while boron is an essential micronutrient to increase the production potential [11].

Recently, according to the soil fertility map Ethiopia soil analysis data revealed that the deficiencies of most of the nutrients such as nitrogen (86%), phosphorus (99%), sulfur (92%), born (65%), zinc (53%), potassium (7%), copper, manganese, and iron were widespread in Ethiopian soils [12]. Similarly, Asgelil *et al.,* [13] found that the soil analyses and site-specific studies also indicated that elements such as K, S, Ca, Mg, and micronutrients (Cu, Mn, B, Mo, and Zn) were becoming depleted and deficiency symptoms were observed in major crops in different parts of the country. The drive for higher agricultural production without balanced use of fertilizers created problems of soil fertility exhaustion and plant nutrient imbalances not only of major but also of secondary macronutrient and micronutrients. Similarly [11] stated that the deficiencies of secondary macronutrient and micronutrients will arise if they are not replenished timely under intensive agriculture. Consequently, to overcome this problem, multi-nutrient balanced fertilizers containing N, P, K, S, B, and Zn in blended form have been issued to ameliorate site-specific nutrient deficiencies and thereby increase crop production and productivity.

Having considered the problems outlined above, the Ethiopian government has been promoting the use of multi-nutrient blend fertilizers since 2015. The promotion of blend fertilizer follows from the results of the soil fertility survey and preparation of the regional nutrient deficiency atlas of the country under the Ethiopian Soil Information System project [12]. To supply sulfur and Boron commercial fertilizer, DAP is replaced by NPS-B. Since the composition of newly introduced fertilizer differs from that of familiar fertilizer (DAP), the appropriate rate is not determined, and insufficient information for potato production in the study area. Therefore, the main purpose of this study was to investigate the optimum rate of NPS-B and by supplementing N from urea for maximum yield of Potato production and to determine economically optimum rates of NPS-B and by supplementing N from urea fertilizer at Bule district, Southern, Ethiopia.

MATERIALS AND METHODS

Description of experimental area

The experiment was carried out in Bule, southern heigh land of Ethiopia during the 2019-2020 main growing season. Geographically the site was located at N 06° 15" 21' E 38° 26"31' and with an altitude of 2675 *m. a. s l.* The mean annual rainfall of the site is 1401-1800 mm, with the mean average temperature ranging between 12.6°-20°C. The rainfall is bimodal with long growing periods from mid-March to the end of October, about 87% of the total rainfall of the area occurs from mid-June to mid-September, with its peak in June and August, and which caused soil loss and nutrient leaching. The dominant soil type of experimental site was Chromic Luvisols. This soil originated from kaolinitic minerals which are inherently low in nitrogen phosphorus cations exchange capacity, pH, and high exchangeable acidity.

Experimental set-up and procedure

The experimental sites were prepared for sowing using standard cultivation practices and were plowed using oxen-drawn implements. The experiment was laid out in randomized complete block design with three replicates for each treatment and detail of the treatments (Table 1). Belate potato variety was used for this experiment. The Boron blended and TSP fertilizers were basal

Table 1: Detail of treatment set up and nutrient levels.

Trt No	Urea (kg ha^{-1})	NPS-B (kg ha^{-1})	Nutrient level (kg ha^{-1})			
			N	P	S	B
1	Control	0	0	0	0	0
2	Rec-N and P		92	62	0	0
3	150	150	96.15	54.15	10.05	1.05
4	150	200	105.2	72.2	13.4	1.4
5	150	250	114.25	90.25	16.75	1.75
6	150	300	123.3	108.3	20.1	2.1
7	250	150	142.15	54.15	10.05	1.05
8	250	200	151.2	72.2	13.4	1.4
9	250	250	160.25	90.25	16.75	1.75
10	250	300	169.3	108.3	20.1	2.1
11	350	150	188.15	54.15	10.05	1.05
12	350	200	197.2	72.2	13.4	1.4
13	350	250	206.25	90.25	16.75	1.75
14	350	300	215.3	108.3	20.1	2.1

Note: The nutrients level of in 100 kg of NPS-B were (19 N–36.1 P_2O_5-0.0 K_2O+6.7 S+0.0 Zn+0.71 B).

applied once at planting. To minimize losses and increase efficiency, N fertilizer (urea) was applied in the row in two applications: half at planting and the other half 40 days after planting, during the maximum growth period, after first weeding, and during light rainfall to minimize N loss. Lime ($CaCO_3$) was evenly broad cast manually and mixed thoroughly in upper soils at 15 cm plow depth applied uniformly for all experimental units one month before seed sowing based on exchangeable acidity and the lime requirement was calculated by formula.

$$LR, CaCO_3\,(kg/ha) = \frac{cmolEA/kg\ of\ soil * 0.15\,m * 10^4\,m^2 * B.D.(Mg/m^3) * 1000}{2000}$$

Soil sampling and analysis

Representative composite surface soil samples were collected from 0-20cm depth at each experimental unit just before sowing. After manual homogenization, the samples were ground to pass a 2 mm sieve. Soil particle size distribution was determined by the Boycouos hydrometric method [14]; pH of the soils was measured in water suspension in a 1:2.5 (soil: water ratio) [14] organic carbon was determined using the wet oxidation method [15]; total nitrogen was determined using Kjeldahl digestion with concentrated H_2SO_4 and $K_2SO_4^-$ catalyst mixture [16]; available P was determined using the Olsen method [17]; total sulfur in soil extracts was done using Turbidimetric method. The cation exchange capacity was determined after extracting the soil samples by ammonium acetate method (1N NH_4OAc) at pH 7.0 [18]. Exchangeable acidity (EA) Al^{+3} and H^+ were determined from a neutral 1N KCl extracted solution through titration with a standard NaOH solution [19].

Crop sampling, harvesting, and data collection

Randomly five plants were collected for growth and yield component data. Plant height, biomass, marketable tuber yield, and un-marketable tuber yield, and other parameters were recorded.

ECONOMIC ANALYSIS

Economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget and marginal analyses were used. Current prices of barley, Urea, TSP, and NPS-B fertilizer were used for the analysis. The potential response of crop towards the added fertilizer and price of fertilizers during planting ultimately determine the economic feasibility of fertilizer application [20]. The market cost of marketable potato yield 25.00 Eth-birr kg^{1}. The prices for blended fertilizers NPSB, TSP, and Urea were 21.54, 21.54, and 19.12 Eth-birr kg^{1}, respectively. The cost of other production practices likes, seed and weeding were assumed to remain the same or insignificant among the treatments. Analysis of the Marginal Rate Of Return (MRR) was carried out for non-dominated treatments, and the MRRs were compared to a Minimum Acceptable Rate Of Return (MARR) of 100% to select the optimum treatment [20]. The net benefit per hectare for each treatment is the difference between the gross benefit and the total variable costs. The average yield was adjusted downward by10% to reflect the difference between the experimental field and the expected yield at farmers' fields and with farmer's practices from the same treatments [20].

Statistical analysis

Data from the field and laboratory were tested for normality, before being subjected to Analysis Of Variance (ANOVA) using SAS software program version 9.4 [21]. The significant difference among treatment means was evaluated using the least significant difference at ($p \leq 0.05$).

RESULTS AND DISCUSSION

Soil physicochemical properties of the experimental sites before sowing

Soil laboratory analysis result shows that soil particle size distributions experimental site soil was 41%, 21.1%, and 37.5 % sand, silt, and clay, respectively. Thus, the soil textural class of the soils of the site was clay loam. The pH value of the soil was 5.12 (*1:2.5 soil: water*) which is strongly acidic soil [22]. The soil pH has a vital role in determining several chemical reactions in influencing plant growth by affecting the activity of soil microorganisms and altering the solubility and availability of most of the essential plant nutrients particularly the micronutrients such as Fe, Zn, B, Cu, and Mn [23]. The organic carbon% and total nitrogen content% of the soil were 2.01% and 0.41% respectively Table 2. According to [22] organic carbon% and total nitrogen content % of the soil was medium/moderate. The available P content soil was 11.75 mg kg^{1} which is medium [24].

Whereas, the cation exchange capacity of 22.48 Cmolc kg^{1} and rated as moderate according to [25].

Effects of NPS-B blended fertilizer and nitrogen on potato tuber yield

The analysis of the result revealed that the application of different rates of NPS-B blended fertilizer brought a highly significant ($p<0.01$) effect on all of the measured variables. The pooled mean result shows that the marketable tuber yield of potato obtained from the application of 350 kg ha^{-1} of NPS-B and 250 kg ha^{-1} of Urea fertilizers were superior to all of the other treatments. The maximum marketable tuber yield of (37.8 tone ha^{-1}) and unmarketable tuber yield (3.4 tone ha^{-1}) and total maximum tuber yield (41.1 tone ha^{-1}) were obtained from the application of 250 kg ha^{-1} of NPS-B and 350 kg ha^{-1}. However, the inferior tuber yield of potato attributes was obtained from control (unfertilized) treatment. Application of 250 kg ha^{-1} of NPS-B and 350 kg ha^{-1} of Urea fertilizers were superior in marketable tuber yield by 31.9% and 75.4% from recommended NP and control or unfertilized plot. The higher amount of fertilizer received plot produced the maximum amount of tuber yield that of the lower-level fertilized plots. This is because potato demands high levels of soil nutrients due to its relatively poorly developed, coarse, and shallow root system [26]. The crop produces much more dry matter in a shorter life cycle that results in large amounts of nutrients removed per unit time, which generally most of the

Table 2: Soil physicochemical properties of soil.

Properties	Values
pH-H_2O (1:2.5)	5.12
Sandy (%)	41.4
Silt (%)	21.1
Clay (%)	37.5
Textural class	Clay loam
Total nitrogen	0.25
Organic carbon (%)	2.01
Available phosphorous mg kg^{1}	11.75
Available S (%)	1.17
CEC Cmolc kg^{1}	22.48

soils are not able to supply [27].

Similarly, this could be attributable to the fact that in such conditions, vegetative growth of the aerial parts can be enhanced and translocation of photosynthetic matters into the storage parts increased [5]. Likewise, the application of nitrogen with the addition of sulfur nutrients had a positive or synergetic effect [6,11]. This positive interaction could be important in boosting crop yield. Also, sulfur is required for the production of chlorophyll and utilization of phosphorus and other essential nutrients. Sulfur ranks equal to nitrogen for optimizing crop yield and quality [11]. Similarly, Sharma *et al.*, [28,29] reported that the application of sulfur fertilizer resulted in significant differences in yield, and raising the level 0 to 45 kg ha^{-1} increased total tuber yield per plant by 32.55%. The increase in tuber yield with increasing S levels may be due to its role in the synthesis of sulfur-containing amino acids, proteins, energy transformation, and activation of enzymes which in turn enhances carbohydrate metabolism and photosynthetic activity of plant with increased chlorophyll synthesis and partitioning of the photosynthates in the shoot and tubers [28]. Application of sulfur-containing fertilizers like NPS improves the availability of plant nutrients like P, Fe, Mn, and Zn, by amending the soil pH that may in turn increase yields of vegetable crops including potato [11]. Generally, the present study results revealed that application of NPS-B fertilizer increased tuber yields of potato in agreement with the findings of different researchers who reported positive response of potato for tuber yields with increasing levels of NPS-B fertilizer rates at different agro-ecologies [30-35]. The results are generally in agreement with the findings of different researchers who reported positive response of potato varieties for tuber yields with increasing levels of different blended fertilizer rates at different areas [36,37] (Table 3).

Table 3: Mean values of tuber yield of potato as influenced by NPSB and Urea in 2019-2020 cropping season at Bule.

Treatments (kg ha^{-1})		Year								
		2019			2020			Pooled Mean		
Urea	NPS-B	MTY (t ha^{-1})	UMTY (t ha^{-1})	TTY (t ha^{-1})	MTY (t ha^{-1})	UMTY (t ha^{-1})	TTY (t ha^{-1})	MTY (t ha^{-1})	UMTY (t ha^{-1})	TTY (t ha^{-1})
Control		16.5^{e}	1.3^{d}	17.8^{f}	17.7^{e}	1.2^{h}	18.9^{g}	17.1^{g}	1.3^{g}	18.4^{g}
RNP		25.8^{bcde}	2.7	28.5^{bcde}	29.1^{b}	2.8^{bc}	31.8^{bc}	27.4^{bcd}	2.7^{cdef}	30.2^{bcd}
150	150	18.9^{f}	3.1^{abc}	22.0^{f}	20.9^{de}	2.1^{g}	22.9^{fg}	19.9^{fg}	2.6^{def}	22.5^{fg}
150	200	21.3^{ef}	2.7^{abc}	24.0^{ef}	23.1^{cde}	2.1^{g}	25.3^{efg}	22.2^{efg}	2.4^{ef}	24.6^{ef}
150	250	21.4^{ef}	3.0^{abc}	24.3^{ef}	23.2^{cde}	2.4^{defg}	25.7^{efg}	22.3^{efg}	2.7^{def}	25.0^{ef}
150	300	29.8^{b}	3.7^{a}	33.5^{b}	21.6^{de}	2.4^{defg}	24.1^{fg}	25.7^{bcde}	3.0^{abcd}	28.8^{bcd}
250	150	28.4^{bc}	2.3^{c}	30.8^{bcd}	23.9^{bcde}	2.3^{efg}	26.1^{cdef}	26.1^{bcde}	2.3^{f}	28.5^{bcd}
250	200	28.5^{bc}	3.2^{abc}	31.7^{bc}	27.8^{bc}	2.7^{cde}	31.4^{bc}	28.1^{bc}	2.9^{abcde}	31.6^{bc}
250	250	22.7^{cdef}	3.1^{abc}	25.8^{cdef}	28.5^{bc}	2.6^{cdef}	31.0^{bcd}	25.6^{cde}	2.8^{abcde}	28.4^{cde}
250	300	30.1^{b}	3.5^{ab}	33.6^{b}	29.0^{b}	2.9^{bc}	31.9^{b}	29.6^{b}	3.2^{abc}	32.8^{b}
350	150	21.8^{def}	2.9^{abc}	24.7	24.3^{bcd}	2.6^{cde}	26.9^{bcdef}	23.0^{efg}	2.8^{abcde}	25.8^{ef}
350	200	23.5^{cdef}	3.5^{abc}	26.9^{cdef}	23.5^{cde}	3.1^{ab}	26.6^{bcdef}	23.5^{efg}	3.3^{ab}	26.8^{de}
350	250	38.7^{a}	3.2^{abc}	41.8^{a}	36.9^{a}	3.5^{a}	40.4^{a}	37.8^{a}	3.4^{a}	41.1^{a}
350	300	27.7^{bcd}	2.5^{bc}	30.2^{bcde}	27.6^{bc}	2.7^{bcde}	30.2^{bcd}	27.6^{bc}	2.6^{def}	30.2^{bcd}
CV		14.1	20.0	14.3	12.8	10.9	15.6	13.5	17.5	12.7
LSD@≤0.05		31.2**	3.9*	35.3**	27.7**	4.3*	25.3**	23.3**	1.9*	24.9**

Means with the same letter along the column are not significantly different at $p \leq 0.05$, where-UMTY-unmarketable tuber yield, MTY- marketable tuber yield, TTY-tuber yield.

Table 4: Economic analysis of yield.

Treatments	ATY (kg ha^{-1})	GB (Eth- birr)	TVC (Eth- birr)	NB (Eth- birr)	MRR%
1	15.4	477090.0	0.0	477090.0	
3	17.9	555210.0	6099.0	549111.0	72021.0
2	24.7	764460.0	6731.9	757728.1	329.6
4	20.0	619380.0	7176.0	612204.0	d
7	23.5	728190.0	8011.0	720179.0	129.3
5	20.1	622170.0	8253.0	613917.0	d
8	25.3	783990.0	9088.0	774902.0	192.8
6	23.1	717030.0	9330.0	707700.0	d
11	20.7	641700.0	9923.0	631777.0	d
9	23.0	714240.0	10165.0	704075.0	298.8
12	21.2	655650.0	11000.0	644650.0	d
10	26.6	825840.0	11242.0	814598.0	702.3
13	34.0	1054620.0	12077.0	1042543.0	273.0
14	24.8	770040.0	13154.0	756886.0	d

Where: ETB=Ethiopian Birr (currency); TCV=Total cost that vary; NB = Net benefit; MRR=ATY-adjusted tuber yield, GB=Growth benefit, Marginal rate of return; Price for urea, NPS, TSP and barley grain; 19.12, 21.75, 21.75, 28.5 Eth- birr kg^{-1} respectively.

Economic Analysis

As indicated in Table 4, the highest net benefit of 1042543.0 ETB ha^{-1} with a marginal rate of return (MRR) of 273.0% was obtained in response to the application of 250 kg ha^{-1} of blended NPSB with 350 kg ha^{-1} of Urea. However, the lowest net benefit was obtained from an unfertilized or control plot. Thus, applications of 250 kg ha^{-1} NPSB of blended plus 350 kg ha^{-1} of urea is economically advisable for farmers in the study area for better bread wheat production; beneficial as compared to the other treatments in the study area because the highest net benefit and the marginal rate of return were above the minimum level (100%) (Table 4).

CONCLUSION

The result of the current study indicated that balanced and adequate soil nutrient management is one important practice for increasing bread wheat yield component and yield. The result of the economic analysis showed that combined application of 200 kg ha^{-1} of NPSB and 250 kg ha^{-1} of urea gave economic benefit. Therefore, it could be concluded that the application of 200 kg ha^{-1} of NPSB with supplement 250 kg ha^{-1} of urea fertilizer combinations were producing economically profitable grain yield of bread wheat. Thus, this rate of fertilizer would be recommended for the study area.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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