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Determination of NPSB Fertilizer Rates For potato (*Solanum tuberosum* L.) production at high-altitude of Guji zone, Southern Oromia, Ethiopia

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ABSTRACT

Potato is a key food security and cash crop in the Guji zone, facing challenges from climate change, poor agronomic practices, and soil fertility depletion. A field experiment was implemented to determine optimal NPSB fertilizer rates to enhance potato production. The treatments comprised of seven rates of NPSB (0, 50, 100, 150, 200, 250 and 300 kg ha-1) combined with a fixed nitrogen application 46 kg of N ha-1 , using the Bubu variety in a randomized complete block design. Results indicated that NPSB significantly affected flowering time, maturity, plant height, and tuber yields, with 250 kg ha-1 yielding the highest marketable tuber yield (37.58 t/ha) and net benefit (1,002,560 ETB/ha). The application of 250 kg NPSB ha-1 is thus recommended for economic viability in the region.

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INTRODUCTION

Potato (*Solanum tuberosum* L) is one of the most important crops that contribute to food security on a global scale, due to its high yield per unit of cropland and time (Devaux *et al*., 2014). Potato is a resilient crop that can secure vulnerable livelihoods under the effects of climate change and changing market environments. Potato also improves food security because it is a source of employment and income, both of which have direct links to household food access and nutrition (Kanter *et al*., 2015). In tuber crops potato known as perfect food and underground apple (FAO, 2022), and transitional crop during severe and prevailing food shortage that occur every year (Semagn *et al*., 2007).

Moreover, potato yields more food more rapidly on less land than any other major crop. In Ethiopia, the potato crop is nutritionally rich staple foods that contribute carbohydrates, protein, vitamin C, vitamin A, zinc, iron, and minerals which alleviate the problem of malnutrition in subsistence farmers and towns (Abebe, 2019). Potato is cultivated worldwide in over one hundred countries throughout Africa, Asia, Australia, Europe, and North and South America (USDA-ARS, 2014). It is native to South America (Eskin *et al*, 1989). Potato was first cultivated by the Incas of Peru 6000 years ago by Incas in Peru (Nunn and Quinn, 2011; Ugent *et al*., 1982).

Potato was introduced to Ethiopia in 1859 by a German Botanist called Schimper (Berga *et al.,* 1994). The crop ranks first in area overage and third in both total production and productivity among the root crops grown in Ethiopia (CSA, 2022). Potatoes are among the most widely-grown crop plants in the world giving good yield under various soil and weather conditions (Lisinska and Leszcynski, 1989). Generally, Potato requires altitude between 1800 to 2500 (Bezabih and Mengistu, 2011), optimum soil temperature 16-19°C (Anonymous, 2004), high rainfall ranging between 1000 and 1500 mm per year (Gusha, 2014), temperate climates (Humans, 2003) Potatoes grow best in loose, well-drained, non-crusting, sandy loam or loam soils with high organic matter content and pH between 5.5 and 6.5(Biswas *et. al*., 1991; Martha and Ann, 2017).

The amount and availability of plant nutrients in the soil significantly influence plant growth rate, maturity time, size of plant parts, and biochemical content of plants and seed capabilities (White *et al*. 2007). In Eastern Africa, Ethiopia is the major producer of potato, and 70% of the arable land is suitable for potato cultivation b/c of suitable agro ecology but the average national yield of potato 16.687 tha^{-1} (CSA, 2022), the average yield of potato yield (29.4tha^{-1}) in Guji zone (Dembi *et al*., 2017) also it is very low as compared to the yield in developed countries 40 to 50 tha^{-1}(FAO, 2023). The low yield is due to lack of high yielding varieties, poor soil fertility, diverse climatic condition, lack of appropriate agronomic practices, diseases and insect pests (Adane *et al*, 2010 , Haverkort *et al.,* 2012, Gebremedhin, 2013 , Tewodros, 2014, and Egata , 2021). Potato is as a high yielding crop and heavy feeder takes up a lot of nutrients from the soil at a given time and requiring large quantities of fertilizers. Potatoes take up approximately 40-50% of their N and K needs and about 30-40% of the P and S requirements prior to tuber bulking (Westermann 2005). In the other hand low soil fertility is one of the limiting factors to sustain potato production and productivity in Ethiopia (Olango, 2008).

The soil fertility mapping project in Ethiopia reported that deficiency of K,,S, Zn, B and Cu in addition to N and P in major Ethiopian soils were common (Ethio-SIS, 2014).Know a day, the Ministry of Agriculture of Ethiopia has been recently introduced a new blended fertilizers and so no those fertilizers which containing nitrogen, phosphorous, sulfur, boron, zinc, potassium and so on (Tegbaru, 2016). Depletion of soil nutrients other than N and P could be additional reason for the observed decrease in yield gains (Wassie and Tekalign, 2013).

Potato is one of the most important food security and cash crop for farmers in highland parts of Ethiopia, particularly in Guji zone where it is grown abundantly. Even though, potato is such an important tuber crops in Guji zone. The low yield of potato due to a number of production problems that accounts for low regional as well as national yield have been identified: lack of improved varieties and germplasm for diverse agro-ecologies, lack of formal seed system (dominated by informal), diverse climatic condition, poor appropriate agronomic practices (spacing, fertility, ridging) and diseases and insect pests (Abebe, 2019, and Egata, 2021). Since soil test based and site specific nutrient management has been a major tool for increasing prod uctivity of agricultural soils. Current fertilization rates are insufficient to sustain high yields and to replenish nutrie nt removal by the crop (Imas and Bansal, 1999). Potato yield could be increased by 50% only by improved nutri ent management (Grewal *et al*., 1993).Potato has strict requirement for a balanced fertilizer management and is the most responsive crop (Alam *et al.*, 2007).

In Ethiopia the soil fertility mapping reported that deficiency of K, S, Zn, B and Cu in addition to N and P (Ethio-SIS, 2014). Fertilizer recommendations made vary across diverse agro ecologies in Ethiopia particularly in Guji zone. This situation is challenging for the researchers, agricultural office workers and farmers to understand the effects and the optimum rates of NPSB fertilizer that contains sulfur, boron, and zinc for production of potato. According to 2018 soil map of Bore and Ana sora districts showed that deficient of N, P, S and B nutrients, but the rates of applications were not identified. Due to this reason, large and small scale potato producers, Agricultural office experts, and farmers have no information about recommended updated fertilizers for two districts. Therefore, this research was conducted with the objectives of to determine the optimum rates of NPSB fertilizer and to assess the cost and benefit of different rates of NPSB fertilizer application for potato production in high land areas of Guji zone.

MATERIALS AND METHODS

Description of the Experimental Site

The field experiment was carried out during the 2023-2024 cropping season in the highland areas of Guji zone at Bore on- station, Ana sora on-farm. The first experiments were located at the Bore research site at a distance of about 8 km north of the town of Bore in Songo Bericha Kebele' just on the side of the main road to Addis Ababa via Hawassa town. Geographically, the experimental site is situated at the latitude of 06°23'55''N and longitude of 38°35'5''E at an altitude of 2728 m above sea level. The major soil type is clay in texture and strongly acidic with a pH value of 5.1 (Arega, 2020). The second experimental site was located at Anna Sora at a distance of about 30 km East of the town of Bore in Raya Boda Kebele' just on the side of the main road to Addis Ababa via Adola town. Geographically, the experimental site is situated at the latitude of 06°10'N and longitude of 380°380'E at an altitude of 2451 m above sea level and the soil type is Clay (Tekalign *et al.,*2019).

Experimental Materials

An improved potato variety called 'Gudane', Blended NPSB (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B), and Urea (CO ([NH_2]$_2$) (46% N) were used for the study.

Treatments, Experimental Design, and Field Management

The treatment consists of seven (7) levels of blended NPSB rates (0, 50, 100,150,200,250 and 300 kg ha^{-1}) and plus 100 kg Urea ha^{-1}was applied to all plots equally. The experiment were laid out as a Randomized Complete Block Design (RCBD) and replicated three times per treatment. A plot size of 3 m x 3 m and spacing of 75cm and 30cm between rows and plants respectively as well as three rows per plot and 40 tubers per plot were used. All pertinent management practices was carried out following the recommendation of the crop. The middle two rows were used to for data collection. Plants in the two outer rows as well as those at both ends of each row were not considered for data collection to avoid edge effects.

Table 1. List of experimental treatments, fertilizer compositions and their descriptions

No.	Treatments		Total composition of fertilizer in the treatment (kg ha^{-1})			
	Blended NPSB rate (kg ha^{-1})	N-rate (kg ha^{-1})	N	P_2O_5	S	B
1	0	46	46	0	0	0
2	50	46	55.45	18.85	3.475	0.05
3	100	46	64.9	37.7	6.95	0.1
4	150	46	74.35	56.55	10.425	0.15
5	200	46	83.8	75.4	13.9	0.2
6	250	46	93.25	94.25	17.375	0.25
7	300	46	102.7	113.1	20.85	0.3

Soil Sampling and Analysis

The composite soil samples were collected by using Auger (Soil sampler) from 0-20 cm depth based on the procedure outlined by Taye *et al*. (2000) and using the zigzag method (Carter and Gregorich, 2008). The collected samples were sent to soil at Horti coop Ethiopia soil and water analysis laboratory by using soil analyzed method (Table 2).

Table 2: Selected physico-chemical properties and analyzed method used

Soil property to analyzed	Soil analyzed method used
pH (1: 2.5 soil H_2O ratio)	1:2.5 soils & H_2Omixture by using a pH meter(Rhoades, 1982).
Organic matter (%)	by multiplying the OC% by a factor 1.724.
Organic carbon (%)	Walkley and Black method (Walkley & Black, 1934)
Total N (%)	Kjeldhal Method (Jackson, 1958).
CEC (meq/100 g soil)	Ammonium acetate (Chapman, 1965).
Available P (ppm)	Bray II methods (Bray and Kurtz, 1945).
Soil texture	Bouyoucos Hydrometer Method (Bouyoucos, 1962)
Available potassium(ppm)	Melich-3 methods (Mehlich, 1984).
Exchangeable Bases[Cmol$_{(+)}$kg^{-1}soil]	
Exchangeable K,Mg,Na, Ca, and Al	Melich-3 methods (Mehlich, 1984).

Data collection

Phenology, Growth, yield and yield components were collected:- Days to 50% flowering, Days to 90% maturity, Plant height (cm), Steam Number hill^{-1}, Tuber number hill^{-1}, Tuber weight (g/tuber), Marketable tuber yield (t ha^{-1}),Unmarketable tuber yield (<200mm,isect attacked, cracked, diseased, deformed) (t ha^{-1}), and Total tuber yield(t ha^{-1})

Partial Budget Analysis

The partial economic analysis was carried out by using the methodology described in CIMMYT (1988).Only the cost that varied among different treatments was taken into account. The yield of the crop was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers expect from the same treatments. The treatment which gives the highest NB and a MRR greater than the minimum is considered acceptable to farmers (>1 or 100%).To compare the costs that varied with the net benefits, the marginal rate of return was calculated as

NB = TR – TVC

$$MRR\% = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Varaible Cost } (\Delta TVC)} \times 100$$

Data Analysis

Field data were analyzed by using Gen Stat *18th* Edition software for the data following the standard procedures outlined by Gomez and Gomez (1984). Comparisons among the treatment means were done using Duncan's Multiple Range Test (DMRT) tests at 0.05 level of significant.

RESULTS AND DISCUSSIONS

Physico-Chemical Soil Properties of the Experimental Site

The results of laboratory analysis revealed that high total nitrogen and available P levels in the experimental soils of Bore and Ana sora, according to Ethio SIS (2014). The soil's available P ranged from 0-15 to 0.5, with low available phosphorus due to fixation in acidic soils. At increased soil acidity (low pH), phosphorus is fixed to surfaces of Fe and Al oxides and hydrous oxide, which is not readily available to plants (Sikora *et al*., 1991). P-deficiency leads to reduction in most metabolic processes, including cell division, cell expansion, respiration and photosynthesis (Marschner, 1995). The soil's available sulfur ranged from 7.72 to 9.64 mg kg^{-1}very low available S. S-deficiency plants have poor utilization of nitrogen, phosphorus and potash at all age (Haq and Hossain, 2003). The soils CEC ranged between 32.44 and 38.28 meq/100 g, with high to very high nutrient holding capacity and water holding capacity. The soils organic carbon content was high (Table 3). The soils pH was rated strongly to moderately acidic, with phosphorus fixed to surfaces of Fe and Al oxides and hydrous oxide, which are not readily available to plants. Therefore, the soils pH is a critically important chemical property, which has a major influence on nutrient availability. Fortunately, potatoes can be grown successfully in soils with pH values as low as 5.5 or lower.

Table 3. Selected physicochemical properties of the experimental soil before planting in 2023/24 'belg' cropping season

Soil parameters	Soil result at pre planting		Rating	Reference
	Bore on station	Ana sora		
pH (1:2.5 H2O)	5.12	5.86	Strongly to moderately acidic	Ethio SIS (2014)
OC (%)	3.56	3.24	high	Tekalign (1991)
TN (%)	0.34	0.34	high	Ethio SIS (2014)
P (mg/kg ppm)	4.30	4.52	very low	Ethio SIS (2014)
S (mg/kg ppm)	9.64	7.72	very low	Karltun (2013)
B (mg/kg ppm)	0.38	0.58	medium to very low	Ethio SIS (2014)
K (mg/kg ppm)	92.42	328.58	Optimum	Ethio SIS (2014)
CEC (meq/kg soil)	32.44	38.28	high to very high	Murphy (2007)
Sand	32	34	-	-
Clay	34	40	-	-
Silt	28	26	-	-
Textural class	Clay	Clay	clay	(USDA,1987)

Mean Squares of Potato Parameters

The analysis of variance across years and locations revealed that rates of NPSB fertilizer significantly ($P \leq 0.05$) influenced days of 50% flowering, days to 90% maturity, plant height, and number of tuber per hill, marketable tuber yield, and total tuber yield of potato. However, rates of NPSB fertilizer did not manipulate ($P > 0.05$) the number of stem per plant, tuber weight, or unmarketable tuber yield of potato (Table 4).

Table 4. Mean squares of ANOVA for Irish potato Phenology, growth, yield and yield component determination of NPSB fertilizer- rates at Bore on-station and Ana Sora on-farm in 2023 cropping season

Source of Variables	Parameters								
	DF	DM	PH	SN	TN	TW	MTY	UnMTY	TTY
Rep.	36.61*	0.11ns	68.12ns	4.72ns	1.02ns	870.03ns	2.48ns	0.92ns	0.53ns
NPSB	126.95**	129.41**	450.83**	3.43ns	24.36**	555.58ns	318.55**	1.63ns	299.72*
Loc	2453.76**	2486.29**	2761.97**	37.50**	2.28ns	25760.01**	277.36ns	19.00*	441.69*
Yr	6589.71**	6222.96**	2457.33**	23.71**	139.26**	750.01ns	1615.34**	7.49ns	1842.79**
NPSB *Loc	5.06ns	30.21*	7.70ns	1.73ns	2.99ns	335.20ns	22.97	3.22ns	26.50ns
NPSB *Yr	58.35**	52.15**	57.97ns	0.45ns	5.52ns	183.26ns	37.55	0.57ns	44.30ns
NPSB *Loc*Yr	99.16**	96.13**	56.43ns	1.79ns	2.39ns	2493.64**	30.36ns	0.73ns	34.06ns

*, & ** Significant at P<0.05 and P<0.01, respectively, DF=Days to 50% flowering, DM= Days to 90% maturity, PH=Plant height (cm), SN= Steam Number hill^{-1},TN= Tuber number hill^{-1},TW=Tuber weight (g/tuber), Marketable tuber yield (t ha^{-1}), UnMTY(t ha^{-1})= Unmarketable tuber yield (t ha^{-1}) & TTY= Total tuber yield(t ha^{-1})

Phonological and Growth Parameters

Days to flowering, maturity, plant height and numbe r of stems per plant

The combined mean revealed that the latest days to 50% flowering and days to 90% maturity fertilizer (70.00 and 102.91) were obtained with the application of 300 kg NPSB ha^{-1} fertilizer rate and followed (67.83 and 98.91) with the application of 250 kg NPSB ha^{-1} fertilizer rate while the earliest days to 50% flowering and 90% maturity (60.83 and 93.16) was recorded with the nil received plots of NPSB fertilizer (Table 5).

The delaying flowering and maturity might be due to the role of NPSB fertilizer in extending the vegetative growth of potato crop. The delayed flowering and maturity of plants in response to the application of NPSB fertilizer at higher rates might be due to the effect of nitrogen stimulated plant growth, enlarged leaves and tubers but delayed flowering and maturity. This suggestion is in agreement with that of Tantowijoyo and Van de Fliert (2006) that the application of nitrogen fertilizer at higher rates enhances vegetative growth by helping the plant to absorb sunlight and produce carbohydrates.

This result is also in agreement with the results of Zelalem *et al.* (2009), Biruk *et al*. (2015) and Gezahegn *et al*.(2021) who reported that application of N and P fertilizers delayed flowering and physiological maturity of potato. Moreover, the application of higher rates of NPSB fertilizer might be due to sufficient supply of nutrient that promotes vegetative growth and delayed the crop in attaining reproductive stage. This result is in agreement with, who reported that application of NPSB fertilizers delayed flowering and maturity stages of potato (Gezahegn *et al*., 2021). In contrast with the results of this study, Minwyelet *et al*. (2017) and Getachew *et al.* (2016) reported that there were no significant differences required for days to flowering in potato due to the application of blended fertilizer

The rate of NPSB fertilizer increased to the highest rate from 0 to 300 kg ha^{-1}, markedly increase in plant height was observed such that the tallest plant height (81.46cm) was recorded at the highest NPSNB rate of 300 kg ha^{-1}, while the shortest plant height (63.68 cm) was recorded for the control (Table 5). This may be attributed the enhancing influence of NPSB role on plant height as N plays vital role in cell division, elongation and vegetative growth of plants (Marschner, 1995). The highest number of stem per plant (6.89) was recorded at100 kg/ha NPSB fertilizer rate application, while the lowest number stem per plant (5.40) was recorded the nil received plots of NPSB fertilizer(Table 5).Number of stem per plant might be influenced due to the different tuber size that we have used as planting material. Number of stem is not influenced much by mineral nutrient rather by other factors such as storage condition of tubers, number of viable sprouts at planting, sprouts damage at time of planting and growing conditions (Allen, 1978).

Table 5. Combined mean performance of phenology and growth of potato evaluated at Bore on-station and Ana Sora on-farm in 2023/2024-2024/25 cropping season

Treatments NPSB- rates kg ha^{-1}	Days to 50% flowering	Days to 90% maturity	Plant height (cm)	Steam Number per hill
0	**60.83e**	**93.16d**	**63.68d**	**5.40**
50	61.83de	94.33cd	69.79c	5.78
100	64.91c	95.08cd	79.53a	**6.89**
150	63.33cd	96.66bc	72.64bc	6.17
200	65.58bc	97.66b	73.18bc	5.69
250	67.83ab	98.91b	77.52ab	6.68
300	**70.00a**	**102.91a**	**81.46a**	6.03
Mean	64.90	96.96	73.97	6.09
LSD(0.05)	2.34	2.55	5.81	NS
CV (%)	4.40	3.21	9.6	23.86

Where, *, & ** Significant at P<0.05 and P<0.01, respectively, CV: Coefficient of variation, LSD: Least significant difference, and NS: Non-significant

Yield component parameters

Numbers of tuber per plant and Tuber weight

The maximum number of tuber per plant (11.60) was recorded with the application rate of 100 kg NPSB ha^{-1} fertilizer application and followed (10.57) with the application of 300 kg NPSB ha^{-1} while the lowest (7.15) was recorded with the nil received plots of NPSB fertilizer (Table 6). The results of this study showed that the importance of NPSB application to maximize the tuber number per hill recorded 100kg/ha rather than at high rates. This result is in line with that of Getachew (2016) who reported the highest total tuber number per hill was obtained from 250 kg NPSB ha^{-1}.The highest tuber weight (115.54) was recorded with the application rate of 200 kg NPSB ha^{-1} with the application rate and followed (102.62) with the application of 250 kg NPSB ha^{-1} while the lowest (96.25) was recorded with the nil received plots of NPSB fertilizer (Table 6). Increasing the rate of the blended NPSB application from nil to 200 kg ha^{-1} significantly increased the average tuber number per hill by about 20.04%. The increase in average tuber weight of tubers in response to the increased supply of fertilizer nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthesis which may have induced formation of bigger tubers thereby resulting in higher yields (Patricia and Bansal, 1999). The results of the present studies are consistence with the findings of various researchers (Melkamu *et al*., 2018; Minwyelet *et al*., 2017) who reported that the application of NPS fertilizer increased mean tuber weights of potato. In contrast with this study result of Israel *et al*. (2012) and Biruk *et al.* (2015) stated that the application of nitrogen and phosphorus not influenced average tuber weight of potato.

Table 6. Combined mean performance of yield components of potato evaluated at Bore on-station and Ana Sora on-farm in 2023/2024-2024/25 cropping season

Treatments NPSB- rates kg ha^{-1}	Tuber number per hill	Tuber weight (g/tuber)
0	**7.15d**	**96.25**
50	8.83c	102.00
100	**11.60a**	98.37
150	9.48bc	99.16
200	9.98bc	**115.54**
250	8.88c	102.62
300	10.57ab	**95.45**
Mean	9.50	101.34
LSD(0.05)	1.55	NS
CV (%)	20.02	22.19

Where, *, & ** Significant at P<0.05 and P<0.01, respectively, CV: Coefficient of variation, LSD: Least significant difference, and NS: Non-significant

Tuber yield Parameters

Marketable tuber yield, Unmarketable tuber yield and Total tuber yield

The maximum marketable tuber yield (37.58tha^{-1}) was obtained with the application of 250 kg NPSB ha^{-1} fertilizer rate and followed (32.52tha^{-1}) with the application of 200 kg NPSB ha^{-1} fertilizer rate(Table 7). Increasing the rate of blended NPSB fertilizer from nil to 250 kg ha^{-1} increased marketable tuber yield significantly. This increment amounted to about 75.36%. However, further increasing the rate of the fertilizer from 250 kg ha^{-1} beyond which no increment was recorded the marketable tuber yield of potato (Table 7). 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.

On the hand, reduction in yield due to high rate of N application could be explained by a phenomenon that extra nitrogen application often stimulates shoot growth at the expense of tuber initiation and bulking (Sommerfeld and Knutson, 1965). This result is consistent also with those of Minwyelet *et al*. (2017) and Melkamu *et al*. (2018) who reported that the application of NPS fertilizer at the rate of 272 kg ha^{-1} resulted in the production of the highest marketable tuber yield (47.02 t ha^{-1}) of potato. It is also consistent with this result, Iseal *et al*. (2012) and Zelalem *et al*. (2009) reported that increasing the application rates of nitrogen and phosphorus resulted in increasing total tuber yield. Minwyelet *et al*., (2017) and Melkamu *et al*. (2018) reported that the rate of 272 kg blended NPS ha^{-1} resulted in the production of the highest total tuber yield (47.53 t ha-1) while application of no blended NPS fertilizer produced the lowest total tuber yield (17.32 t ha^{-1}). Getachew *et al*. (2016) also reported that application of 100 kg blended NPKSZ ha^{-1} fertilizer resulted in the highest total tuber yield whereas the lowest tuber yield was obtained in response to nil application of the fertilizer. Morover, Abato *et al*. (2024) reported that incr easing blended NPSB fertilizer application increased tot al tuber yields of potato

Table 7. Combined mean performance of tuber yield of potato evaluated at Bore on-station and Ana Sora on-farm in 2023/2024-2024/25 cropping season

Treatments NPSB- rates kg ha^{-1}	Marketable tuber yield (t/ha)	Unmarketable tuber yield (t/ha)	Total tuber yield (t/ha)
0	**21.43c**	3.68	**25.11c**
50	26.94bc	3.01	29.96bc
100	32.67ab	3.85	36.52ab
150	28.88b	3.36	32.24bc
200	32.52ab	3.00	35.53ab
250	**37.58a**	2.90	**40.49a**
300	32.23ab	3.08	35.31ab
Mean	30.32	3.27	33.59
LSD(0.05)	7.12	NS	7.31
CV (%)	28.70	46.64	26.59

Where, *, & ** Significant at P<0.05 and P<0.01, respectively, CV: Coefficient of variation, LSD: Least significant difference, and NS: Non-significant

Correlation analysis

The correlation analysis revealed significant relationships between various agricultural parameters influenced by NPSB fertilizer rates. A positive correlation was found between the number of stems per plant and the number of tubers per plant (r = 0.377). Conversely, the number of tubers per plant showed a weak negative correlation with tuber weight (r = -0.028). Marketable tuber yield exhibited strong positive correlations with Days to 50% flowering (r = 0.584), Days to 90% maturity (r = 0.526), plant height (r = 0.414), number of stems per plant (r = 0.527), number of tuber plants (r = 0.441), and total tuber yield (r = 0.989). Additionally, several parameters had weak negative correlations with tuber weight. Correlation coefficients ranging from +1 to -1 indicate the strength of the relationships among the studied variables.

Table 8. Correlation analysis rates of NPSB fertilizer application rates to potato at Bore on-station and Ana sora on-farm in 2023/2024-2024/25 cropping season

Character	Character DF	DM	PH(cm)	SN	TN	TW (g)	MTYld (t/ha)	UnMTYld (t/ha)	TTYld (t/ha)
DF	1	0.955**	0.21*	0.49**	0.439**	-0.376*	0.584**	0.308*	0.61**
DM		1	0.187ns	0.469**	0.417**	-0.35**	0.526**	0.295*	0.551**
PH (cm)			1	0.144ns	0.473**	0.237*	0.414**	-0.123ns	0.383*
SN				1	0.377*	-0.313*	0.527**	0.319*	0.556**
TN					1	-0.028ns	0.441**	0.264ns	0.466**
TW (g)						1	0.011ns	-0.202ns	-0.018ns
MTYld (t/ha)							1	0.154ns	0.989**
UnMTYld (t/ha)								1	0.295*
TTYld (t/ha)									1

Where, *, & ** Significant at P<0.05 and P<0.01, respectively, DF=Days to 50% flowering, DM= Days to 90% maturity, PH=Plant height (cm), SN= Steam Number hill^{-1},TN= Tuber number hill^{-1},TW=Tuber weight (g/tuber), Marketable tuber yield (t ha^{-1}), UnMTY(t ha^{-1})= Unmarketable tuber yield (t ha^{-1}),TTY= Total tuber yield(t ha^{-1})

Partial Budget Analysis

The study confirmed that the application of 250 kg NPSB fertilizer per hectare resulted in the highest net benefit of Birr 1,002,560 and a marginal rate of return (MRR) of 5545.45%, which exceeds the acceptable threshold (100%). In contrast, untreated plots produced a much lower net benefit of Birr 578,610. The 250 kg NPSB ha-1 application not only maximized financial returns but also yielded the highest marketable tuber output of 33,822 kg ha^{-1}, proving profitable for farmers (Table 9).

Table 9. Partial budget analysis determination the rates of NPSB fertilizer for potato production

Treatments NPSB- rates kg ha^{-1}	**Unadjusted MYLD (kgha^{-1})**	**Adjusted MYLD (kgha^{-1})**	**Total variable cost**	**Total Revenue**	**Net benefit**	**MRR%**
0	21430	19287	0	578610	578610	-
50	26940	24246	2420	727380	724960	6047.52
100	32670	29403	4840	882090	877250	6292.97
150	28880	25992	7260	779760	772500	D
200	32520	29268	9680	878040	868360	3961.15
250	**37580**	**33822**	**12100**	**1014660**	**1002560**	**5545.45**
300	32230	29007	14100	870210	856110	D

Where, N cost = Birr 20 kg^{-1}, N- fertilizer Application cost 2 persons 50 kg ha^{-1}, each 210 ETB day^{-1}, Field price of Potato during harvesting= Birr 30 birr kg^{-1}, MYLD=Marketable tuber yield, MRR (%)
= Marginal rate of return and D= Dominated treatment.

CONCLUSIONS AND RECOMMENDATION

The experiment was carried out at Bore on station and Ana sora on-farm during the 2023/24 and 2024/25cropping seasons. Results showed significant impact on days to flowering and maturity, plant height, number of tubers, and marketable yield, but not on stem count, tuber weight, or unmarketable yield. The optimal application rate of 250 kg NPSB/ha yielded the highest marketable tuber yield (37.58t/ha) and net benefit

(1002560.00 ETB/ha), with a marginal rate of return of 5545.45%. Therefore, 250 kg NPSB/ha is recommended for farmers in the area for economically viable potato production.

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