

## Response of Potato (*Solanum tuberosum* L.) to NPSB Fertilizer Rate and Inter Row Spacing at Buno Bedele Zone

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### Abstract

Potato is a key tuber crop in Ethiopia, contributing significantly to food security and rural livelihoods. However, its productivity remains low due to factors such as improper fertilizer application and unsuitable inter-row spacing. This study was conducted during the 2022–2023 cropping season to evaluate the effects of NPSB fertilizer rates and inter-row spacing on potato yield and yield components. Four NPSB levels (50, 100, 150, and 200 kg ha<sup>-1</sup>) and three inter-row spacings (65, 75, and 85 cm) were tested, along with a control, using a 4 × 3 factorial arrangement in a randomized complete block design with three replications. Analysis of variance revealed significant effects of both NPSB rate and spacing on all measured parameters, though their interaction was not significant. The highest marketable tuber yield (51.36 t ha<sup>-1</sup>) was obtained with 200 kg ha<sup>-1</sup> NPSB, while the widest spacing (85 cm) produced 45.16 t ha<sup>-1</sup>. Agronomic efficiency was greatest (152.4 kg kg<sup>-1</sup>) at the lowest NPSB rate (50 kg ha<sup>-1</sup>). Marketable tuber yield showed strong positive correlations with total tuber yield ( $r = 0.99^{**}$ ), average tuber weight ( $r = 0.92^*$ ), and large tuber size ( $r = 0.92^{**}$ ). Partial budget analysis indicated the highest net benefits of 1,231,355 birr ha<sup>-1</sup> (3823.92% MRR) for NPSB and 2,120,240 birr ha<sup>-1</sup> (11,444.83% MRR) for 85 cm spacing. Therefore, applying 150 kg ha<sup>-1</sup> NPSB fertilizer with 85 cm inter-row spacing is the most productive and economically viable practice for potato cultivation in the study area.

**Keywords:** Potato, NPSB, Inter Row Spacing

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### Introduction

Potato (*Solanum tuberosum* L.) is originated in the highlands of South America (Asfaw, 2016). It is fourth and third most important food crop in the world in terms of production and in terms of consumption respectively. It is one of the important tuber crops grown worldwide, fourth and third most important food crop in the world in terms of production and in terms of consumption respectively. Report of IPC showed that about billion people eat potato in worldwide particularly; developing countries. Moreover, potato is also suited to smallholder farmers in developing countries for the labor requirement (Devaux et al., 2021). It is a staple food consumed by almost two-thirds of the world's population, and in 2020, 359.07 million tons were produced worldwide (Degebasa, 2019; Campos & Ortiz, 2020; Dongyu, 2022)

Ethiopia is endowed with suitable climatic conditions for potato production. Around 70% of cultivated farming land in Ethiopia is suitable for potato production (Tadesse et al., 2017). Still, the national average potato yield in Ethiopia is 16.69 t ha<sup>-1</sup>, which is lower than world average yield up to 20 t ha<sup>-1</sup>. Besides, the yield of potato in Ethiopia is lower than that of most potato producing countries in Africa like South Africa and Egypt, which produce 34 and 24.8 t ha<sup>-1</sup>, respectively.

Despite its great significance in the farming system of the country, Potato production is constrained by many confounding circumstances that include low soil fertility, periodic moisture stress, diseases-insect pests, lack information about a variety, unavailability of improved varieties, and limited or improper application of fertilizers and irrigation (Alemayehu et al., 2025). However, among these inappropriate agronomic practices like fertilizer application rates and inter spacing are the main constraints of potato production in the country (Israel et al., 2012; Alemayehu et al., 2015).

In case of spacing, plant spacing plays a crucial role in potato cultivation. Besides, as plant density increases, there is a patent decrease in plant size and yield per plant. This effect is due to increased inter-plant competition for water, light and nutrients (Mulatu & Hagayo, 2024). The blanket recommended plant spacing for all potato varieties in Ethiopia is 75 cm by 30 cm between rows and plants, respectively. On the other hand, farmers in Ethiopia are using different spacing below or above the national recommendation (Arega et al., 2018).

Conversely, on the other hand, soil nutrient status is also the most important parameter that limits the yielding potentials of various crops including potato. Under such conditions, the application of multi-nutrient blended fertilizers is believed to enhance the productivity and nutrient use efficiency of crops (Abdeta et al., 2023). Ethio-SIS reported deficiencies seven nutrients such as nitrogen (86%), phosphorus (99%), sulfur (92%), boron (65%), zinc (53%), potassium (7%) and copper in Ethiopian soils. Subsequently, to overcome this problem, the application of multi-nutrient-based balanced fertilizers containing N, P, K, S, B, and Zn in blended form would be essential to increase crop production and productivity. Thus, Ethiopian government has been encouraging the use of balanced nutrient-based blend fertilizers since 2013. To supply nutrients such as sulfur and boron, the earlier used DAP was replaced by NPSB.

In the past farmers use DAP and Urea as blanket recommendation. Solomon et al. (2021) indicated that blanket application might have led to the depletion essential elements and consequently not satisfy the nutrient requirements of crops including potato. Accordingly, blended fertilizers, such as NPSB (18.9% N, 37.7% P<sub>2</sub>O<sub>5</sub>, 6.95% S, and 0.1% B) are currently being used by the farmers in the study area based on the recommendation drawn from soil fertility map of the areas [20]. Nevertheless, the rate of blended fertilizer (NPSB) was not determined. Thus, farmers use inappropriate rates of fertilizer (NPSB) due to lack information on the application rates. Therefore, it needed to determine optimum rates of blended fertilizers (NPSB).

In the study area, information for potato production fertilizer rate and inter row plant spacing is limited for optimum tuber yield. Hence, determining optimum NPSB fertilizer and inter row spacing for potato production is very important to come up with relevant recommendations that can optimize potato tuber yield. Thus, the objective of this experiment was to determine effects of blended (NPSB) fertilizer rates and inter row spacing on yield and yield components of Potato that economically viable in the study area.

## Methods

### Description of The Study Area

The experiment was conducted on two and one farmer's field during the 2022-2023 cropping highland agro-ecosystems of Gechi and Chora district, Oromia Regional National State, southwestern Ethiopia. Gechi district is located 475 km southwest of Addis Ababa and bordered on the south by Didessa, on the east by the Jimma Zone, on the north by Bedele, and

on the east by the Didessa River which separates it from the Jimma Zone. The experimental site receives an average annual rainfall of 1850mm with maximum and minimum temperatures of 18<sup>0</sup>c and 21<sup>0</sup>c, respectively (Abdeta et al., 2023). There are two distinct seasons: the rainy season starting in late March and ending in October and the dry season occurring from November to early March. Chora is located 519 km away from the capital city of the country and 36 km away from Bedele Town of Buno Bedele Zone. It is generally characterized by warm climate with a mean annual maximum temperature of 25.5°C and a mean annual minimum temperature of 12.5°C. The annual rainfall ranges from 1440 mm. The soil of the area is characterized as an old soil called Niti soils.

### Experimental Material

The experiment was conducted using Belete as test crop. This variety was released by Holeta agricultural research center in 2009. The variety was selected based on its adaptation and better performance in the area. Blended NPSB (18.9% N, 37.7% P<sub>2</sub>O<sub>5</sub>, 6.95% S and 0.1% B) was used as the source of fertilizers.

### Treatment and Experimental Design

The experiment were consisting of three inter row spacing (65, 75 and 85cm) and four levels of NPSB fertilizer rates (50,100,150 and 200 kg ha<sup>-1</sup>) with one control. 100 kg ha<sup>-1</sup> of urea was used in each plot except control plot as a constant rate based on blanket recommendation. The treatments were laid in randomized complete block design with three replication. Each experimental unit had 4.55m length and 3m width with a total net area of 13.65m<sup>2</sup> each experimental unit length is divided into 7, 6 and 5 rows at 65cm, 75cm and 85cm intervals, respectively.

Table 1. Treatments Combination For Effect Of NPSB and Inter Row Spacing For Potato Crop

No	Rates NPSB (Kg/ha)	NPSB Fertilizer Composition (kg/ha)				Inter Row Spacing	Combination
		N	P <sub>2</sub> O <sub>5</sub>	S	B		
1	0	0	0	0	0	75	control
2	50	9.45	18.85	3.48	0.05	65	50*65
3	50	9.45	18.85	3.48	0.05	75	50*75
4	50	9.45	18.85	3.48	0.05	85	50*85
5	100	18.9	37.7	6.95	0.1	65	100*65
6	100	18.9	37.7	6.95	0.1	75	100*75
7	100	18.9	37.7	6.95	0.1	85	100*85
8	150	28.35	56.55	10.43	0.15	65	150*65
9	150	28.35	56.55	10.43	0.15	75	150*75
10	150	28.35	56.55	10.43	0.15	85	150*85
11	200	37.8	75.5	13.9	0.2	65	200*65
12	200	37.8	75.5	13.9	0.2	75	200*75
13	200	37.8	75.5	13.9	0.2	85	200*85

NPSB=Nitrogen, Phosphorus, Sulfur and Boron

### Data Collection

Days to emergence was the number of days from planting to 50% emergence was used as days to emergence for statistical analysis. Days to 50% flowering was recorded by counting the number of days from planting to when 50% of plants in each plot flowered. Days to Physiological maturity was recorded when the haulms (vines) of 90% of the plant population per plot turned yellowish or showed senescence. Plant height was measured from the ground surface to the tip of the main stem at physiological maturity from five randomly selected plants from the middle rows. Average stems number was number of stems raised from the ground from randomly selected five plants was counted when 50% of the plants in each plot attained flowering stage and mean number of only stems that had directly grown from the mother tuber and acted as an independent plant above the soil were considered as stems. Stems branching from other stems above the soil were not considered as main stems. Tuber number was total number of tubers harvested from five randomly selected plants grown in the net plot area was counted and mean tuber number per plant/hill was computed and used for further analysis purpose (Zelalem et al., 2009).

Marketable tuber yield was tubers which was free of diseases, insect pest damages and above 25g in weight were considered as marketable tubers as indicated by Lung'aho. The weight of such tubers harvested from the net plot area was measured using scaled balance and expressed as ton per hectare. Unmarketable tuber yield was tubers which was diseased and insect pest attacked and less than 25g, misshaped and decayed are considered as unmarketable tuber as indicated by Lung'aho. Average tuber weight was recorded by dividing total fresh weight of tubers by the total number of fresh tubers per plot (Burga et al., 2013). Tuber size category was tubers which were large (>75g), medium (25-75g) and small (<25g). Total tuber yield was recorded by sum of weights of marketable and unmarketable. Agronomic Efficiency is described as the economic production obtained per unit of Fertilizer applied and was calculated as:  $AE = \frac{YF - Y0}{F}$  (Kg kg<sup>-1</sup>) Where, YF is the grain yield of a fertilized plot (kg ha<sup>-1</sup>), Y0 is the grain yield of the control plot (kg ha<sup>-1</sup>), and F is the amount of NPSB or applied (kg ha<sup>-1</sup>).

### Soil Sampling and Analysis

A pre-planting soil samples were also collected at a depth of 0-20 cm following the standard method and analyzed for some selected physico-chemical properties of the soil at Bedele Research Center following the standard manual. Accordingly, determination of soil particle size distribution was carried out using the hydrometer method. Soil pH was measured using digital pH meter in 1:2.5 soils to water ratio. Cation exchange capacity of the soil was determined following the modified Kjeldahl procedure Chapman (1965) and reported as CEC of the soil. Percent base saturation was calculated from the sum of exchangeable basis as a percent of the CEC of the soil. Organic carbon was determined following wet digestion methods as described by Walkley & Black (1934) whereas kjeldahl procedure was used for the determination of total N as described by Jackson. The available P was measured by Bray II method.

### Data Analysis

All the measured parameters were subjected were first checked for all assumptions of ANOVA. Then the data were subjected to Analysis of Variance (ANOVA) and simple correlation analysis was performed using SAS PROC CORR by SAS version 9.2). The data collected were statistically analyzed using the Analysis of Variance (ANOVA) procedures Means were separated using the LSD test to signify the treatment differences at a 5% level of probability (Steel & Torrie, 1960).

## Partial Budget Analysis

The economic analysis was done to investigate the economic feasibility of the treatments. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers expected from the same treatment. The average open market price (Birr kg ha<sup>-1</sup>) for potato and the official prices of blended and urea fertilizers was used for analysis. Labor costs was involved for application of blended NPSB fertilizer rates was recorded and used for analysis. The net returns (benefits) and other economic analysis was based on the formula developed by CIMMYT methodology.

## Results and Discussion

### Soil physic-chemical before planting

The laboratory result indicated that soil texture of the study area is dominated by clay and the textural class of soil of experimental site is clay (Table 2). The soil pH of experimental site 5.21, which is strongly acidic according to Tekelign [34]. The organic carbon content of the soil is 4.58% which is medium according to the rating of Landon (Landon, 2014). The medium organic carbon content of the soil might be due to the intensive cultivation and continuous removal of crop residues. Organic carbon in soils influences physical, chemical and biological properties of the soils such as soil structure, water retention, nutrient contents and retention and micro-biological life and activities in the soils. Therefore, restoring the soils with organic fertilizers is important for enhancing crop yields as well as soil health. Total nitrogen (0.34%) was medium according to the rating of EthioSS who classified soil nitrogen content very high (>0.5), high (0.25-0.50), medium (0.15-0.25), low (0.05-0.15). The available soil phosphorus (0.88 mg kg<sup>-1</sup>) of the experimental site was very low. The very low available phosphorus might be due to the high phosphorus sorption and due to high P fixing capacity of the soil in the study area. CEC of study area was 23.51 cmol (+) kg<sup>-1</sup> which classified as medium (Landon, 2014). Medium CEC of the soil might be due to moderate organic matter content and high soil acidity.

Table 2. Selected Soil Physico-Chemical Properties Before Planting of Experimental Sites During 2022-2023

Soil Characteristics	Gechi District		Chora District		Value	
	2022	2023	2022	2023		
Textural class	Clay	Clay	Clay	Clay		[36]
pH	5.21	5.16	5.45	5.24	Strongly Acidic	[34]
OC	4.55	3.73	5.07	4.58	Medium	[34]
Total N (%)	0.39	0.29	0.44	0.34	Medium	[20]
Av P	0.76	0.61	0.71	0.88	very low	[29]
CEC	22.33	18.67	24.63	23.51	Medium	[35]

OC=Organic Carbon, Total N (%)= Total Nitrogen, Av P= Available phosphorus, CEC=Cation exchange Capacity

### Analysis of variance (ANOVA)

The results of a combined analysis of variance showed that the main effect of different levels of applied NPSB and inter row spacing fertilizer rates significantly ( $P < 0.01$ ) affected all parameters (Table 3 and Table 4). On the other hand, the interaction effects of the NPSB application and inter row spacing showed non significant variation in all parameters (Table 3 and 4).

Table 3. Mean Squares of ANOVA for Phenological, and Growth of Potato As Influenced By NPSB Rates and Inter-Row Spacing

Sours of Variation	DF	DE	DF	DM	PH	SN	NT
Rep	2	2.01NS	23.11NS	50.19NS	23.04NS	10.61NS	66.33NS
NPSB	3	1.34*	42.22*	88.32*	105.44*	69.61*	435.06**
IRS	2	0.92*	12.14*	6.03*	40.02*	4.57*	28.58**
NPSB*IRS	6	0.11NS	5.44NS	9.88NS	19.55NS	0.26NS	1.62NS
Error	130	0.31	9.45	7.07	52.29	1.68	10.48

Key: DF= Degree freedom IRS, DE=Days to Emargency, DM=Days to Maturity, PH = Plant Height, SN=Stem Number, TN = Tuber Number, \*= significant,\*\* = Highly Significant and NS=Non-significant

Table 4. Mean Squares Of ANOVA for Yield And Yield Components of Potato As Influenced By NPSB Rates And Inter-Row Spacing

SV	DF	MY	UMY	TY	AVTY	LTS	MTS	STS
Rep	2	626.07NS	11.93NS	712.95NS	2.24NS	0.56NS	80.26NS	16.34NS
NPSB	3	24357.94**	224.48**	29088.21***	3736.42**	931.11**	526.41**	108.46**
IRS	2	3701.25**	32.39**	4404.45**	516.15**	129.04**	34.59**	6.95**
NPSB*IRS	6	53.99NS	9.66**	542.80NS	26.08NS	6.52NS	1.96NS	0.41NS
Error	130	321.71	20.73	339.25	49.13	12.28	12.69	2.63

Key: SV= Source of variation, DF= Degree freedom IRS= Inter-row spacing, TN= Number of tuber, MY=Marketable tuber yield ,UMY=Un Marketable tuber yield, TY=Tuber yield, AVTW=Average tuber weight, LTS=Large tuber size,MTS=Miduem tuber size, \*= significant,\*\*=Highly Significant =NS-Non significant

### Effect f NPSB Fertilizer Rates and Inter Row Spacing on Phenological Parameter Days To 50% Emergence (Days)

Days to 50% emergence was significantly ( $p < 0.05$ ) affected by the main effect of NPSB and inter row spacing. However, non-significant results attributed to interaction effect between different NPSB rates and Inter row spacing with regard to days to emergence (Table 3). Thus, late germination (14.37days) was obtained from the 200 kg ha<sup>-1</sup> NPSB plot and early germination mean (10.23days) was observed from plot received control plot (Table 3). Days to 50% emergence was delayed by about 4 days in 200kg ha<sup>-1</sup> application as compared to control plot. This might be due to the role of increased NPSB fertilizer that enthused growth and prolonged vegetative phase. On othe rhand, 100 and 150 kg ha<sup>-1</sup> of NPSB, fertilizer rates, showed statistically par and significantly different from control plots. Interestingly, Kinde and Asfaw [37] reported similar findings reported that increased application of blended fertilizer delayed the time to attain 50% emergence by 6.0 days. Contrarily to this result Muluneh (2018) reported that increasing the application of blended NPSB fertilizer from 0 to 350 kg ha<sup>-1</sup> did not show significant differences on the time emergence of potato plants.

Regarding to inter row spacing, the minimum and maximum days to 50% emergence has ranged from 10.67 days to 13.55 days by widening the inter row spacing from 65 cm to 85 (Table 5). In this experiment, earlier plant emergence was obtained in closer inter-row spacing (65cm) and the delayed time to attain days to 50% emergence was obtained at wider intra-row spacing (85 cm). Days to 50% Emergence was delayed about 3 days in wider inter row spacing

85cm as compared to closest inter row spacing 65cm). This delay might be due to lesser competition for resource like water, light and nutrients and poor nutrient use efficiency of the crop because of the wider spacing. This result was in line with the findings of Tadesse and Mulugeta who reported that increasing intra-row spacing resulted in delayed time required to reach 50% emergence.

### **Days to 50% Flowering**

The mean result of days to 50% flowering of potato showed that significant ( $P < 0.05$ ) differences Main effect NPSB rates and inter row spacing but not by interaction effect of the two. Accordingly, the earliest days to 50% flowering (64.67 days) was recorded from the control plot; while the longest days required attaining 50% flowering (71.12 days) was recorded from the plot received 200 kg ha<sup>-1</sup> NPSB. 50% flowering delayed by 7 days at 200kg ha<sup>-1</sup> NPSB fertilizer as compared to control plot. This might be attributed to the positive effect of NPSB that stimulated growth and prolonged vegetative phase; thus, delaying the reproductive phase of plants (Diriba-Shiferaw & Tilaye-Batu, 2020). N nutrient in NPSB has high influence in delaying the flowering of potato by prolonging its vegetative growth (Şanlı et al., 2015). Optimum rates application of fertilizer might lead to a general increment of most metabolic processes; however extremely increase in N fertilizer rate can delay the time to flowering (Abrha et al., 2013). The present result is in line with that of Getaneh and Laekemariam Getaneh & Laekemariam (2021) who reported that application of NPS fertilizer showed significant effect on prolonging of time of flowering. Other researchers also reported that increasing fertilizer rates, including NPS prolonged days to flowering and maturity of potato and other vegetable crops in different agro-ecologies (Mekashaw et al., 2020). In case of inter row spacing, varying inter-row spacing showed significant influence ( $P < 0.05$ ) on days to 50% flowering of potato. Minimum and maximum days to 50% flowering ranged from 62.67 days to 67.67 days (Table 3). The delayed flowering of the crop at wider inter row spacing might be due to the space which allows less competition for sun light, water and nutrient and this enabled the crop to maintain physiological activity for a long period, thereby continuing photosynthesis. Mamiru and Geletu (2022) had reported significant differences in days to 50% flowering for potato crop and they reported that, the wider the plant spacing, the delayed to attain 50% flowering.

### **Days to 90% Maturity**

Days to 90% maturity was significantly ( $p < 0.05$ ) affected by the main or sole effects of NPSB rates and inter spacing but their interaction documented insignificant effect (Table 3). Thus, the mean days to 90% maturity has ranged from (110.33–115.67) days due to the application of different rates of blended fertilizers. Maximum mean days to 90% maturity were recorded from application of 200 kg NPSB blended fertilizer ha<sup>-1</sup> was delayed by 5 days whereas the earliest day was attained from control treatment. This delaying might be due the role of NPSB fertilizer in extending the vegetative growth of the crop that led to delayed days to mature. P nutrient in NPSB attributed this to sustained physiological activities of the plants excessive accumulation of photosynthetic assimilates that lead to continued photosynthesis and growth of the plants (Ababiya, 2018). The present study was supported by the findings of Muluneh [46] who reported extending maturity of potato was observed with the increased rate of NPSB fertilizers. Again, this finding was agree with finding of researchers also reported that increasing fertilizer rates, including NPSB prolonged days to maturity of potato and other vegetable crops in different agro-ecologies. Bewuketu also reported that application of blended NPSZnB fertilizer delayed days to attain physiological maturity. Increasing rates of NPSB

fertilizer may promote the vegetative phase of potato plants that may in turn prolong flowering and maturity of the potato plant. This might be attributed from the increased N uptake from the applied NPSB fertilizer that contributes to have excessive haulm development and in turn prolonged days required to attaining 90% maturity. In the same manner, Mean maximum of (114.53 days) to 90% maturity of potato were recorded at wider intra-row spacing (85 cm) and minimum of (111.70 days) were recorded from 65cm inter-row spacing. The result indicated that wider plant spacing allowed lesser competition for sun light, water and nutrient which enhanced potato plant to maintain physiological activity for a long period. This result was supported with the findings of Abrha et al. (2014) who reported that decreasing inter-row spacing resulted in shortening the time required to reach 90% maturity.

Table 5. Main Effects of NPSB Fertilizer Rate And Inter-Row Spacing on Days to 50% Emergence, Days to 50% Flowering and Days To 90% Maturity

Treatment	Day to Emergence	Days to Flowering	Days to Maturity
NPSB (kg ha <sup>-1</sup> )	(Day)	(Days)	(Days)
0	10.23 <sup>d</sup>	64.67 <sup>d</sup>	110.33 <sup>d</sup>
50	12.55 <sup>c</sup>	66.11 <sup>c</sup>	112.67 <sup>c</sup>
100	13.67 <sup>b</sup>	66.67 <sup>c</sup>	112.87 <sup>c</sup>
150	14.19 <sup>b</sup>	68.37 <sup>b</sup>	114.11 <sup>b</sup>
200	15.64 <sup>a</sup>	71.12 <sup>a</sup>	115.67 <sup>a</sup>
Lsd (0.05)	1.13	1.87	1.09
Inter row spacing (cm)			
65	10.67 <sup>c</sup>	62.67 <sup>c</sup>	111.70 <sup>c</sup>
75	12.13 <sup>b</sup>	64.12 <sup>b</sup>	113.67 <sup>b</sup>
85	13.55 <sup>a</sup>	67.67 <sup>a</sup>	114.53 <sup>a</sup>
Lsd (0.05)	1.03	1.67	0.67
CV (%)	3.21	5.11	5.29

LSD (0.05) = least significant differences and CV (%) = coefficient of variation and \*\*=Highly significant

### Effect of Different NPSB Application Rates and Inter Row Spacing on Growth Parameters Plant Height (cm)

The main or individual effects of NPSB rate and inter row spacing significantly ( $p < 0.001$ ) influenced plant height. However, their interaction did not show a significant impact on plant height (Table 2). Increased application of NPSB fertilizer from 0 to 200 kg NPSB ha<sup>-1</sup> had increased the plant height from (78.27cm) to (87.33 cm) and that the highest plant height (87.33) was recorded when 200 kg NPSB ha<sup>-1</sup> and the lowest plant height (78.27 cm) which was recorded under control plot (Table 3). There is significant and linear increase in plant height in response to increasing the rate of NPSB blended fertilizer application and this may be attributed to the critical role phosphorus, Nitrogen and Sulfur and B which plays in enhancing cell division, growth, and stem elongation to meet the demand for the increased plant height.

Moreover, the widening tinter -row spacing from 65 cm to 85cm had significantly influenced the plant height at which it was increased from (80.57 cm) to (83.55cm) respectively. The highest plant height (83.55 cm) was recorded from closer inter-row spacing (65cm) and the

shorter plant height (80.57 cm) was attained from the wider intra-row spacing of 85 cm. The taller plant growth in the narrower might be attributed due to the stiff competition for sun light in closer intra-row spacing. Generally, closer spacing stimulated plants to grow taller with sufficient NPSB fertilizer in the soil in order to meet the light demand of the crop. The significant increase in plant height observed by plants treated at higher rates of NPSB fertilizer also could be due to the fact that P is required in large quantities in shoot and root tips where metabolism is high and cell division is rapid. Similarly, sulfur promotes the formation of chlorophyll, higher photosynthetic activity, vigorous vegetative growth, and taller plants (Sandhu et al., 2024). Therefore, the combined effects of N, P, and S in NPS fertilizer increased the plant height of potato plants. This result has supported by the finding of Getaneh & Laekemariam (2021), that the highest plant height was recorded from closer or narrower inter row spacing.

### Number of Main Stem

The NPSB fertilizer rate and inter row spacing had significant ( $P < 0.05$ ) main stem per hill. However, the interaction effect of the two factors was not significant on main stem number (Table 2). Increasing the rate of NPSB fertilizer increased main stem number per hill linearly. Application 0 to 200 kg NPSB ha<sup>-1</sup> fertilizer rates resulted in significantly higher main stem number. Increasing the rate of the fertilizer application from 0 to 200 kg NPSB ha<sup>-1</sup> increased the of main stems number per hill (Table 3). The highest main stem number (10.01 hill<sup>-1</sup>) were obtained from the application of 200 kg ha<sup>-1</sup> NPSB fertilizer while the shortest main stem number (5.19 hill<sup>-1</sup>) was recorded at the control plot. The significantly tallest plants and highest number of main stems were observed towards the application of higher rates of NPSB fertilizer that might be ascribed to the increased availability of nitrogen in the soil for uptake by plant roots, which might have sufficiently enhanced vegetative growth through increasing cell division and elongation. In line with this result; according to Muluneh (2018) reported that, the highest number of stem (6.48) was recorded on at rates of 350 kg ha<sup>-1</sup> NPB. Moreover, other researchers reported that stem number per hill was significantly affected by the application of phosphorus fertilizer and intra-row spacing (Tesfaye et al., 2013; Zerga et al., 2017; Mumia et al., 2017).

Table 6. Main Effects of NPSB Fertilizer Rate and Inter-Row Spacing on Plant Height and Main Stem Number

Treatment	Plant Height	Number of Main Stem
NPSB (kg ha <sup>-1</sup> )		
0	78.27b	5.19d
50	78.67b	6.65d
100	80.11b	7.47c
150	84.67a	8.87b
200	87.33a	10.01a
Lsd (0.05)	4.08	0.68
Inter row spacing (cm)		
65	83.55a	4.54c
75	81.22b	6.87b
85	80.57b	10.21a
Lsd (0.05)	1.22	3.3
CV (%)	8.67	14.47

LSD (0.05) = least significant differences and CV (%) = coefficient of variation and \*\*=Highly significant.

## **Effect of Different NPSB Application Rates and Inter Row Spacing on Yield and Yield Components of Potato**

### ***Tuber Number Hill<sup>-1</sup>***

Analysis of variance indicated that both the main effects of NPSB fertilizer rate and inter-row spacing had highly significant ( $P < 0.01$ ) effect on tuber number per hill. However, there was no significant interaction effect. The highest total tuber number (26.88) was found from application of 200 kg ha<sup>-1</sup> while the lowest tuber number (12.78) was recorded from control plot. Increasing NPSB application from 0 to 200 kg ha<sup>-1</sup> increased total tuber number. Increase of total tuber number per hill with an increase in NPSB rate could be due to the fact that N can activate the vegetative growth for more photo-assimilate production, while P enhanced the development of roots for nutrient uptake. Correspondingly, Tadesse and Mulugeta have found that increasing the rate of phosphorus fertilizer significantly increased average tuber number per hill of potato. In agreement with the present finding, the authors of Getaneh and Laekemariam reported a significant tuber number increment in response to NPS fertilizer application. P Nutrient in NPSB could have promoted the growth and photosynthesis rate of the plants and tuber formation. Again in agreement with the result of inter-row spacing, Getaneh and Laekemariam reported that planting potato at the wider spacing resulted in the production of higher numbers of marketable tubers hill<sup>-1</sup> than the narrower spacing. In line with this results, Bekele et al. (2020) reported that increasing rates of both N and P from zero to the maximum increased marketable tuber number per hill by 94.6% over the control and the highest unmarketable tuber number (8.63) per hill was obtained from the control plot and the lowest unmarketable tuber number (3.9) was recorded for 110 kg N with 45 kg P ha<sup>-1</sup>. Similarly, Bruk also reported that increasing the rate of NPSB application from 0 to 200 kg ha<sup>-1</sup> linearly and significantly increased marketable tuber number from 13.47 to 22.68 but unmarketable tubers number per hill was decreased from 5.475 to 4.083.

Moreover, a significant difference in total tuber number was observed due to inter row spacing. The highest total tuber number (23.16) was obtained from wider inter row (85cm) spacing fertilizer rate which is statistically the same with 75cm inter row spacing. On the other hand, the lowest total tuber number (21.63) was recorded from 65cm inter row spacing (Table 7). Total tuber number per hill in response to planting the seed tubers at wider and/or intermediate spacing may be attributed low competition between plants for growth factors such as moisture, nutrients, and light and the optimal utilization of the growth factors for photosynthesis and assimilation of carbohydrates to tubers. Similar finding was reported Amare et al. (2022) planting potato at the wider spacing resulted in the production of higher numbers of marketable tubers/hill than the narrower spacing. In agreement with this result, Masarirambi et al [14] reported that the highest plant density having a lower number of marketable tubers per plant and the highest number of tubers was found at wider plant space. Similarly, Zabihi-e-Mahmoodabad et al. (2010) also reported the widest spacing gave the high tuber number of marketable tuber per hill which was significantly different from the closest spacing. In agreement with this result this result, Tesfa also reported that narrow plant spacing resulted in the production of large number of under sized unmarketable tubers as compared to the wider plant spacing.

### ***Marketable Tuber Yield (t ha<sup>-1</sup>)***

Analysis of variance indicated that both the main effects of NPSB fertilizer rate and inter-row spacing had highly significant ( $P < 0.01$ ) effect on marketable tuber number and unmarketable tuber number. However, there was no significant interaction effect. The highest marketable tuber yield ( $51.68 \text{ t ha}^{-1}$ ) were obtained from the application of  $200 \text{ kg ha}^{-1}$  of NPSB fertilizer rate. While the lowest marketable tuber number ( $22.83 \text{ t ha}^{-1}$ ) was recorded from the control plot (Table 6). Increasing NPB application from 0 to  $200 \text{ kg ha}^{-1}$  increased marketable. The increase on marketable tuber yield an increase in NPSB rate could be due to the fact that N can trigger the vegetative growth for more photo-assimilate production, while P enhanced the development of roots for nutrient uptake. The improvement in yield attributes with the application of S could be ascribed to its pivotal role in regulating physiological and metabolic system in plant. Moreover, Marketable tuber yield tuber was significantly affected by inter-row spacing rate. The highest marketable tuber yield ( $45.16 \text{ t ha}^{-1}$ ) was recorded from 85cm inter row spacing while the lowest marketable tuber yield ( $39.65$ ) was recorded from 65 cm interrow spacing. Marketable tuber yield was statistically the same for 75 cm and 85 cm inter-row spacing.

The production of higher marketable tuber yield in response to planting the seed tubers at wider and/or intermediate spacing may be attributed low competition between plants for growth factors such as moisture, nutrients, and light and the optimal utilization of the growth factors for photosynthesis and assimilation of carbohydrates to tubers. This result agrees with the results reported by Girma et al (2017) who reported that the highest marketable tuber yield were obtained from application highest fertilizer rate ( $115 \text{ kg ha}^{-1} \text{ P}_2\text{O}_5$ ) and wider plan spacing (85cm). Similarly Tamirat et al. (2015) also reported that the highest marketable tuber yield ( $3.73 \text{ kg/plot}$ ) and the lowest unmarketable tuber yield ( $0.97 \text{ kg/plot}$ ) were obtained from combination of  $150 \text{ kg ha}^{-1} \text{ N}$  and 30 cm intra row spacing however the lowest marketable tuber yield was obtained from combination of 10cm intra row spacing and without fertilizer. In agreement with the present result Frezgi reported that plants at closest spacing produced significantly higher yield of small tubers as the consequence of higher competition between plants that reduced the marketable tubers yield and increased marketable tubers yield. The present result is also agreed with the findings of many authors Regassa et al. (2016) 2; Anil et al. (2024) that they reported increased application of inorganic fertilizer and plant grown in the closer spacing has revealed the higher increment in the marketable yield of a crop.

### ***Un Marketable Tuber Yield ( $\text{t ha}^{-1}$ )***

The result showed tha main effect of inter-row spacing and NPSB fertilizer rates was highly significantly affect unmarketable ( $p < 0.01$ ). However, their interaction was found nonsignificant. The highest unmarketable tuber yield ( $6.56 \text{ t ha}$ ) was recorded at narrow inter-row spacing (65 cm) and the lowest ( $6.03 \text{ t ha}$ ) was recorded at wider inter-row spacing (85 cm) which is statistically at par with 75 cm. The Unmarketable tuber yield decreased with increasing inter-row spacing. This could be due to the presence of intense inter-plant competition at closer spacing and the consequent result of much small sized tubers contribute to the higher unmarketable yield. Production of high number of unmarketable tubers at narrower spacing may be due to the fact that narrower planting may result in the production of large numbers of stems per unit area, which may lead to stiff competition among plants and tubers for growth factors, rendering the tubers small-sized and underdeveloped. However, wider spacing may result in the production of smaller number of stems per unit area, thereby reducing the competition of growth factors among plants and tubers and leading to the production of large-sized tubers.

The present result indicates that weight of unmarketable tubers per plant decreases with increasing inter-row spacing and vice-versa. This might be due to the fact that at wider spacing the individual plants face less competition and resulted in big sized tubers which are marketable. On the other hand, at closer spacing severe competition between plants resulted small sized tubers which may increase the proportion of unmarketable yield. The results of other researchers also confirmed the present result whereby closest intra row spacing recorded higher yield of small sized tubers as the consequence of higher competition between plants. This result is in agreement with the findings, the intra-row spacing has a marked effect on unmarketable tuber yield, and the highest unmarketable yield recorded from the closer spacing due to higher inter-plant competition, associated with the small sized tubers. The result of this current investigation is in agreement with the work of Frezgi also indicated that closer seed tuber spacing resulted in a significantly higher yield of small-sized tubers as the consequence of higher competition between plants.

### **Total Tuber Yield ( $t\ ha^{-1}$ )**

Total tuber yield was highly significant ( $p < 0.01$ ) affected by NPSB fertilizer rates and inter-row spacing. However, their interaction was found no significant. The highest total tuber yield ( $58.57\ t\ ha^{-1}$ ) was obtained from  $200\ kg\ ha^{-1}$  while the lowest total tuber yield ( $24.33\ t\ ha^{-1}$ ) were obtained from non-treated plots (Table 6). The difference in total tuber yield between the application rate of NPSB exhibited a significant increment on total tuber yield of potato plant. P nutrient from NPSB might enhance the development of roots particularly lateral and fibrous rootlets which in turn contributed to nutrient absorption, photosynthesis, and general physiological processes. Maximum total tuber yield was obtained at wider inter row spacing. The highest total tuber yield ( $51.72\ t\ ha^{-1}$ ) was obtained ( $85\ cm$ ) inter-row spacing whereas the lowest total tuber yield ( $45.70\ t\ ha^{-1}$ ) recorded at the inter-row spacing ( $65\ cm$ ). Similar to this finding, Birahanu and Woldegiorgis reported that wider spacing of  $75\ cm \times 30\ cm$  was appropriate for high yield of potato. Furthermore, Girma et al [59] indicated that the total tuber yields of plants cultivated at the spacing of  $85\ cm$  between rows and  $30\ cm$  between plants exceeded the total tuber yield of plants. In agreement with the present result, Jemberie (2017) also reported that the application of NPS fertilizer at the rate of  $272\ kg\ ha^{-1}$  produced the highest total tuber yield ( $47.53\ t\ ha^{-1}$ ), while potato plants without NPS fertilizer produced the lowest total tuber yield ( $17.32\ t\ ha^{-1}$ ). The present result also agreed with that of results reported by Zabihi et al that increasing planting density of potato resulted in higher tuber yields due to more tubers being harvested per unit area of land. Similarly, Fayera et al also reported that the highest total yield of tubers ( $10377.78\ kg/ha$ ) obtained from application of high nitrogen rate ( $150\ kgN\ ha^{-1}$ ) and at the closest spacing  $10\ cm$  intra row spacing. This result is in agreement with the finding of Ababiya (2018) and Bikila et al (2014) who reported that tuber yield per hectare was reduced due to the shortage of mineral nutrients and insufficient number of plants grown per hectare in wider intra-row spacing as compared to the plants grown at closer intra row spacing. For the current study,  $20\ cm$  intra row spacing was the most efficient for land utilization when combined with  $250\ kg\ NPS\ ha^{-1}$  application.

### **Average Tuber Weight (g)**

Analysis of variance indicated that both the main effects of NPSB fertilizer rate and inter-row spacing had highly significant ( $P < 0.01$ ) effect on average tuber weight. The highest average tuber weight ( $100.84\ g$ ) was obtained from the application of  $200\ NPSB$  fertilizers. On the other hand, the lowest average tuber weight ( $69.66\ g$ ) was recorded from the control plot (Table 4). Average tuber weight increment with increasing fertilizer rate. This result is also in

agreement with Tadesse and Mulugeta who reported the highest average tuber weight from the effect of wider spacing. Misgina (2016) also reported significant response of average tuber weight production of potato with an increased level of N and P nutrients. Again Solomon et al. (2021) reported application of 9.87 NPS doubled the size of average tuber weight as compared with unfertilized plant. Similar to the result of this study, Shaaban & Kisetu (2014) who reported that the heavier average tuber weight were obtained from the increased application of NP fertilizer.

Furthermore, a significant difference in average tuber weight was observed due to NPS fertilizer application. The highest tuber Average tuber weight (93.32g) of potato was recorded at 85 cm inter-row spacing and the lowest tuber weight (86.88 g) was recorded at 65 cm inter-row spacing. Average tuber weight was statistically similar for inter-row spacing of 675 cm and 85 cm (Table 4). The production of tubers with maximum tuber weight recorded with intermediate and wider spacing might be due to the production of optimum number of stems with lesser competition for resource between plants as compared to closer plant spacing. This implies that an increase in density probably causes an increase in competition between and within plants and hence leads to decrease in availability of nutrients to each plant and, consequently, results in decline of mean tuber weight. In line to this study, Arega reported that maximum average tuber weight was recorded for plants planted at intermediate and wider plant spacing, and the lowest result was obtained at closer plant spacing. This result is also in agreement with Bikila et al who reported the highest average tuber weight from the effect of wider intra row spacing.

### Disease Incidence

Potato late blight was the major disease observed on potato during the experimental period. Accordingly, all treatments showed moderately susceptible (30ms) (Table 4) reactions to the disease.

Table 7. Combined Mean Tuber Yield Related Parameters of Potato in 2022-2023 Cropping Season at Gechi and Chora Districts

Treatment	NT(No)	MY (t/ha)	UMY (t/ha)	TY (t/ha)	ATW (g/tuber)	Disease (Blight)
NPSB rates (kg/ha)						
Control	12.78e	22.83e	7.22a	24.33e	69.66e	30Mr
50	17.90d	32.45d	6.39b	37.74d	77.13d	30Mr
100	21.44c	40.10c	6.25b	46.26c	88.65c	30Mr
150	24.22b	46.67b	5.28c	53.06b	95.19b	30Mr
200	26.88a	51.36a	1.5d	58.57a	100.84a	30Mr
LSD (0.05)	1.51	2.64	0.21	2.72	3.26	
CV (%)	14.47	13.31	7.24	11.91	7.75	
P-Value	**	**	**	**	**	
Inter row Spacing						
65	21.63b	39.65b	6.56a	45.70c	86.88b	30Mr
75	22.33ab	43.06a	6.25b	49.31b	91.16a	30Mr
85	23.16a	45.16a	6.03c	51.72a	93.32a	30Mr
LSD (0.05)	1.31	2.29	0.18	2.35	2.83	

CV (%)	14.44	13.31	7.24	11.91	7.75	
P-Value	**	**	**	**	**	

NT=Number of tuber, MY=Marketable tuber yield, UMY=Un Marketable tuber yield, TY=Tuber yield, AVTW=Average tuber weight, Mr=Moderately resistant LSD (0.05)= Least significant differences and CV (%)= coefficient of variation,\*\* =Highly significant.

**Effect of Different NPSB Application Rates and Inter Row Spacing on Tuber Category Large Tuber Size /Plant (G Hill<sup>-1</sup>) (>75g)**

The analysis of variance revealed that main effect of NPSB fertilizer rates and inter row spacing were highly significantly ( $p < 0.01$ ) influenced on large tuber sized (>75g) but interaction effect showed non significant. The NPSB fertilizer rate increased from 0kg to 200 kg ha<sup>-1</sup>, the number of large-sized tuber increased consistently. The highest proportion of large size tubers (40.65%) were produced from the application of 200 kg NPSB ha<sup>-1</sup> and the lowest proportions of large-sized tubers (28.75%) were produced from control plot. The results showed wider plant spacing the yield of large tuber size was increased. This might be due to wider plant spacing had slight competition between plants for nutrients and growth factors than closer plant spacing which lead to produce high yield of large tuber sizes. This result is in agreement with Desta who reported that the proportion of large size tuber was increased with the increasing application of blended fertilizers 100 kg NPSB per ha<sup>1</sup>) and 200 kg ha<sup>-1</sup> NPSB with adjusted N increased yield of large size tuber by 138 and 148%, respectively, as compared to the control. The maximum proportion of large size tubers (36.44%) were produced from plants grown in 85cm inter row spacing and the lowest proportions of large-sized tubers (30.55%) were produced from plants grown at 65 cm (Table 7). The increased proportion of large-sized tubers at wider intra-row spacing might be due to wider plant spacing had slight competition between plants for nutrients and growth factors than closer plant spacing which lead to produce high yield of large tuber and medium tuber sizes. Similarly Lung'aho et al also described that narrower spacing resulted in the production of many stems with in many small-sized tubers whereas wider spacing results in the production of a fewer stems per unit area resulting in the production of fewer large-sized tubers.

**Medium Tuber Size (g hill<sup>-1</sup>) (25-75g)**

The analysis of variance revealed that main effect of NPSB fertilizer rates and inter row spacing were highly significantly ( $p < 0.01$ ) influenced on large tuber sized (25-75g). However interaction effect showed non significant. Thus, the highest proportion of medium size tubers (30.55%) were produced from the application of 200 kg NPSB ha<sup>-1</sup> which is statically par with 50,100,150 kg NPSB ha<sup>-1</sup> fertilizers rate and the lowest proportions of medium size tubers (25.80%) were produced from control plot (Table 6). This is might be due to application of NPSB that conterbut for tuber formation. Plants grown at 65cm plant spacing produced significantly maximum yield of medium tuber sizes than wider plant spacing (85cm) (Table7). Closer plant spacing had high yield of medium tuber sizes than wider plant spacing. Accordingly, the highest medium tuber size 28.37 % was recorded under closer spacing (65cm). While lowest medium size (23.77%) was recorded from wider inter row spacing (85cm). This result might be due to higher number of plants per unit area produced at closer plant spacing than plants at wider spacing which lead to produced high yield of medium tuber size. This result agreed with the inding of Dagne et al reported maximum yield of medium size tubers was recorded for closer spacing (60 × 20 cm) whereas the lowest yield of medium size tuber was observed with wider (75 × 30 cm) plant spacing.

### Small Tuber Size /Plant (g/hill)(<25g)

The analysis of variance revealed that main effect of NPSB fertilizer rates and inter row spacing were highly significantly ( $p < 0.01$ ) influenced on small tuber sized (<25g). The increased NPSB fertilizer rate from 0 to 200 kg ha<sup>-1</sup> decreased the proportion of small in the range between 20.33 to 16.77 %. The highest proportion of small size tubers (20.33%) was produced from control treatment and the lowest proportions of small size tubers (16.77%) was produced from application of 200 kg NPSB ha<sup>-1</sup> which was statically at par with 100 kg NPSB ha<sup>-1</sup> and 150 kg NPSB ha<sup>-1</sup>. As general, the present result showed that increasing the rate of NPSB fertilizer application decreases the proportion of very small size tubers. This could be due to the interaction of nutrients in blended fertilizer and high number of plants produced per unit area at closer plant spacing that results strong competition between plants for nutrients and growth factors and leads to the production of high yield of small tuber size.

Similarly, the highest proportion of small (12.44%) was produced from plants grown at 65 cm inter row spacing and the lowest proportions of small (8.12%) was produced from plots plants grown at 85 cm which is statically par with 75cm inter row spacing (Table 7). The decrease in number of small-sized tubers at increasing inter-row spacing might be due to high interspecific competition at high plant density. Increase in density may increase the competition between and within the plants and hence lead to decrease in the availability of nutrients for each plant. The result agree with the finding of Getaneh and Laekemariam who reported that increase in plant density decreases mean tuber size probably because of plant nutrient elements reduction increases in interspecies competition and large number of tubers produced by high number of stems. Moreover, Nebiya reported that increased P application from 0 to 138 P<sub>2</sub>O<sub>5</sub> kg ha<sup>-1</sup> decreased the very small sized tuber % of potato from 6 to 2.27%. Similarly, Biruk also reported that increased NPSB fertilizer rate application from 0 to 200 kg ha<sup>-1</sup> decreased the small sized tuber % of potato from 39.73 to 30.27 %. More interestingly, in agreement with the present result Ayalew et al. (2021) also reported that increasing plant density significantly increased the percentage of small-sized tubers. In similar to the current study, decreased plant population density revealed increased small sized tubers per hill was reported by different scholars.

Table 8. Combined Mean Tuber Category of Potato in 2022-2023 Cropping Season at Gechi and Chora Districts

Treatment	Tuber Category		
	Large Tuber Size (>75g)	Miduem Tuber Size (25-75g)	small Tuber Size (<25g)
NPSB (kg ha <sup>-1</sup> )			
0	28.75d	25.80c	20.33a
50	35.80c	26.55c	18.17b
100	36.16b	27.33b	18.09b
150	36.56b	28.27b	17.44c
200	40.65a	30.55a	16.77c
Lsd (0.05)	1.37	2.01	0.89
Inter row spacing (cm)			
65	30.55c	28.37a	12.44a
75	34.17b	25.95b	9.67b
85	36.44a	23.77c	8.12b

Lsd (0.05)	2.07	1.77	1.29
CV (%)	7.75	14.89	14.51

LSD (0.05) = least significant differences and CV (%) = coefficient of variation and \*\*=Highly significant

### Agronomic use Efficiency ( $kg\ kg^{-1}$ )

Agronomic efficiency is the amount of harvestable grain yield per kg of applied nutrient. Agronomic efficiency (AE) was significantly affected by NPSB rates. The highest agronomic efficiency ( $152.4\ kg\ kg^{-1}$ ) was obtained at the application of  $50\ kg\ NPSB\ ha^{-1}$  followed by agronomic efficiency of  $100\ kg\ NPS\ ha^{-1}$  while the lowest value ( $142.65\ kg\ kg^{-1}$ ) was recorded for  $200\ kg\ NPSB\ ha^{-1}$  (Figur 1). The increase in agronomic efficiency at a lower rate of NPSB application and its decrease at higher rates might be due to the rate of increase in seed yield being lower than the rate of increase in NPSB supply. This result was supported by the results reported by Desta that the lowest agronomic efficiency (32.53) was obtained from application of  $200\ kg\ ha^{-1}NPSB$  while the highest agronomic efficiency (78.11) was obtained from treatment that received 100% NPSB. This result is in line with Alemaayhu et al. who indicated that matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield. Fageria et al (2008) also reported that an efficient plant is one that produces higher economic yield with optimum quantity of applied or absorbed nutrient.

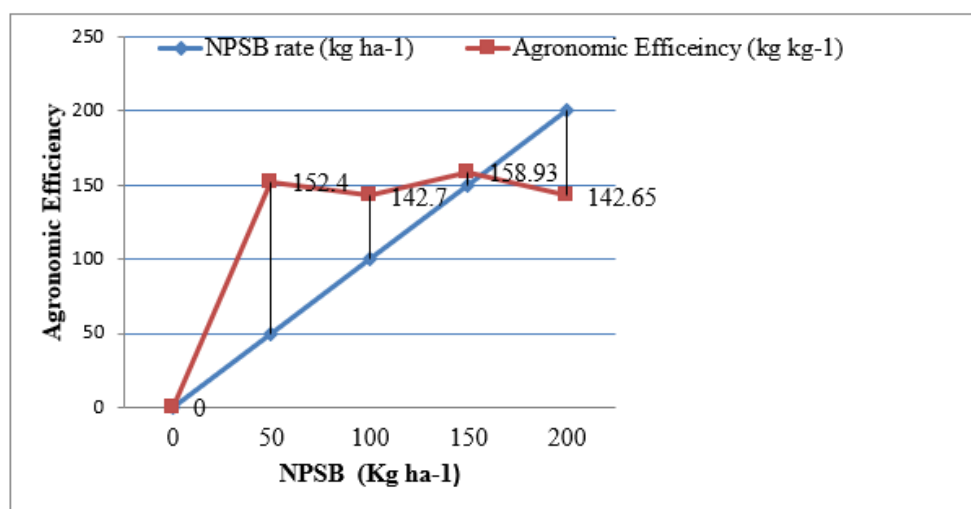


Figure 1. Effect of NPSB Agronomic Efficiency

### Correlation Analysis Among Growth and Yield Parameters

The correlation analysis was performed to determine correlation coefficient between growth and yield parameters as affected by NPSB fertilizer rate and inter-row spacing. Thus, the result indicated that plant height was positively correlated with number of stem ( $r=0.26^*$ ), number of tuber ( $r=0.23^*$ ), Medium tuber size ( $r=0.21^*$ ) and small tuber size ( $r=0.21^*$ ). likewise, number of main stem highly significantly strong correlated with number of tuber ( $r=0.99^{***}$ ), Marketable yield ( $r=0.48^{**}$ ), total tuber number ( $r=0.48^{**}$ ) large tuber size ( $r=0.39^{**}$ ), medium tuber size ( $r=0.97^{**}$ ) and small tuber size ( $r=0.98^{**}$ ). Moreover, Number of tubr per hill was strongly correlated with number of main stem ( $r=0.99^{***}$ ), Marketable yield ( $r=0.48^{**}$ ), unmarketable yield ( $r=0.35^{**}$ ), total tuber yied ( $r=0.48^{**}$ ), Average tuber weight ( $r=0.39^{**}$ ), large tuber size ( $r=0.39^{**}$ ), medium tuber size ( $0.99^{**}$ ) and small tuber size

( $r=0.98^{**}$ ). Similarly, Marketable tuber yield was strogly correlated with tuber number ( $r=0.49^{**}$ ), total tuber yield ( $r=0.99^{***}$ ), Average tuber weight ( $r=0.92^{***}$ ), large tuber size ( $r=0.92^{***}$ ), Medium tuber size ( $r= 0.46^{**}$ ) and small tuber size ( $r=0.46^{**}$ ) (Table 9).

Table 9. Correlation on Growth, Yield and Tuber Yield Traits in Gechi and Chora District During The 2022-2023 Cropping Season

	PH	NMS	NT	MY	UMY	TTY	AVTW	LTS	MTS	STS
PH	1									
NMS	0.26*	1								
NT	0.23*	0.99***	1							
MY	0.09ns	0.48**	0.49**	1						
UMY	0.06ns	0.35**	0.35**	0.72**	1					
TTY	0.08ns	0.48**	0.48**	0.99***	0.76***	1				
AVTW	0.08ns	0.39**	0.39**	0.92***	0.74***	0.93***	1			
LTS	0.08ns	0.39**	0.39**	0.92***	0.74***	0.93***	0.99***	1		
MTS	0.21*	0.97***	0.98***	0.48**	0.35**	0.48**	0.39**	0.39**	1	
STS	0.21*	0.98***	0.98***	0.46**	0.35**	0.48**	0.39**	0.39**	0.98**	1

PH = Plant height; NMS = Number of main stem; NT= Number of tuber; MT= Marketable tuber; UMT= Unmarketable tuber; TTY= Total tuber yield; AVTW = Average tuber weight;LTS=Large tuber size;MTS=Medium tuber size ;STZ=Small tuber size, \*\*\* Very highly significant, \*\* =highly significant and ns=non significant.

### Partial Budget Analysis

The partial budget analysis revealed that the maximum net benefit of Birr 1231355 ha<sup>-1</sup> with marginal rate of returns (MRR) of 3823.92% was estimated for plants that received 150 kg ha<sup>-1</sup> blended NPSB fertilizer. The lowest net benefit of Birr 604995ha<sup>-1</sup> was obtained from plants that did not receive blended NPSB fertilizer and iter row spaced at 65 cm612730 intra-row spacing (Table 10). Furthermore, compared to other inter row spacing the highest net benefit (2120240-birr ha<sup>-1</sup>) with an acceptable marginal rate of return (11444.83%) was obtained when 85cm inter row spacing was used (Tables 10). While the lowest net benefit of Birr 12730 ha<sup>-1</sup> was obtained from inter row spaced at 65 (Table 10).

Table 10. Result of Economic Analysis for Response of Potato Tuber Yield to NPSB Fertilizer Rates and Inter Row Spacing

NPSB rate (kg ha <sup>-1</sup> )	AGY	GFB	TVC	NB	MRR%
0	20547	616410	11415	604995	0
50	27405	822150	17025	805125	3567.38
100	33390	1001700	22150	979550	3403.41
150	42003	1260090	28735	1231355	3823.92
200	46224	1386720	32880	1353840	2955.01
Inter Row spacing (cm)					
65cm	27585	1655100	42370	1612730	0
75cm	33354	2001240	46950	1954290	7457.64
85cm	36144	2168640	48400	2120240	11444.83

Note: AdTY = Adjusted tuber yield kg ha<sup>-1</sup>, GB = Gross Benefit, TVC = Total Variable Cost, NB= Net Benefit and MRR= Marginal Rate of Return

### Conclusion

Potato is one of the important tuber crops of the world including Ethiopia, contributing to nutrition, livelihoods, cultural heritage, and food security across the country. Its continued cultivation and development are essential for sustaining rural economies and ensuring the well-being of Ethiopian communities. However, despite holding a significant agricultural importance in Ethiopia, potato cultivation faces certain challenges in enhancing its production and productivity. Among such challenges, limited information regarding how different food barley varieties respond to various nutrient management practices, inadequate availability of improved barley varieties and improper or insufficient application rates of fertilizers, particularly nitrogen, which is essential for optimal barley production are most notable. The evidence about optimum spacing and Fertilizer application rates for potato production deserves growers' attention as it is influenced by soil fertility status, crop variety, soil moisture status, and their interaction. Thus, agronomic and economic responses of potato under varying inter-row spacing and NPSB fertilizer rates were studied Buno Bedele zone. The result revealed that growth and yield parameters were significantly affected only by main effects of NPSB rates and inter-row spacing only but not by interaction effect. Hence, application of 200 kg NPSB kg ha<sup>-1</sup> resulted maximum marketable tuber yield (51.36t ha<sup>-1</sup>) and total tuber yield (58.57 t ha<sup>-1</sup>) while lower yield were obtained from control treatment. Furthermore, the highest marketable tuber yield (45.16 t ha<sup>-1</sup>) and total tuber yield (51.72t ha<sup>-1</sup>) were obtained from the inter-row spacing of 85cm whereas the lowest result for these parameters were recorded at 65 cm. Application of NPSB fertilizer on potato exceed non-application both in yields and net benefits. Remarkably, the lowest NPSB rate (50 kg ha<sup>-1</sup>) demonstrated the highest agronomic nitrogen use efficiency. The partial budget analysis revealed that the highest net benefit obtained (1231355birr ha<sup>-1</sup>) with acceptable marginal rate of return (3823.92%) and (2120240 birr ha<sup>-1</sup>) with acceptable marginal rate of return (11444.83%) from NPSB kg ha<sup>-1</sup> and 85cm inter row spacing respectively. This economic analysis underscores the importance of selecting appropriate varieties and optimizing nitrogen fertilization strategies to enhance barley yield and profitability in agricultural production systems. Therefore, the production of potato with 150 kg ha<sup>-1</sup> NPSB fertilizer rate and 85cm inter row spacing is most productive and economically viable and can be recommended for the study area for further demonstration.

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### Conflict of Interests

The authors have not declared any conflict of interests

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