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

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Abstract

Poor soil fertility and inappropriate agronomic practices are the major constraints that limit potato productivity in Ethiopia. Thus, the study was conducted to determine the effect of NPSB fertilizer rates and inter row spacing on tuber yield and yield components of potato and to identify economically feasible treatments that can maximize the productivity of potato. The experiment was laid out in a randomized complete block design with factorial arrangement in three replications. The treatments consisted of four levels of NPSB (50,100,150 and 200 kg ha^{-1}) fertilizer and three inter row spacing (65, 75 and 85cm) with control treatment which constituted a total of 13 treatments. The results of combined analysis of variance showed that the main effect of NPSB application rates and inter row spacing were significantly affected Plant height, Number of main stem, Number of tuber, Marketable tuber, unmarketable tuber, total tuber yield and average tuber weight. Hence, application of 200 kg ha $^{-1}$ NPSB resulted maximum marketable tuber yield (51.36 t ha^{-1} while lower yield was obtained from control treatment. Furthermore, the highest marketable tuber yield (45.16 t ha $^{-1}$ were obtained from the inter-row spacing of 85cm whereas the lowest result for these parameters were recorded at 65 cm. Conversely, the highest value of agronomic efficiency 152.4 kg kg^{-1} was obtained at lowest NPSB rate 50 kg ha $^{-1}$ while lowest agronomic efficiency 142.65kg kg^{-1}was obtained from highest NPSB 200 kg ha $^{-1}$. The result of correlation analysis showed that there is positive and significant correlation among tuber yield and yield components, such Marketable tuber yield was strongly correlated with tuber number (r=0.49**), total tuber yield (r=0.99***) and average tuber weight (r=0.92***). Besides, the partial budget analysis revealed that the highest net benefit obtained (1231355 birr ha^{-1}) with acceptable marginal rate of return (3823.92%) and (2120240 birr ha^{-1}) with acceptable marginal rate of return (11444.83%) from NPSB kg ha^{-1} and 85cm inter row spacing respectively. Therefore, the production of potato with 150 kg ha $^{-1}$NPSB fertilizer rate and 85 cm inter row spacing is most productive and economically profitable and can be recommended for the study area for further scaling up.

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Keywords

Potato, NPSB, Inter row spacing.

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 (FAOSTAT, 2022). Report of IPC (2020) 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 and Ortiz, 2019; Dongyu, 2022).

Ethiopia is endowed with suitable climatic and endemic conditions for potato production. About 70% of cultivated agricultural land in Ethiopia is suitable for potato production (Yenenesh *et al.,* 2017). However, the national average potato yield in Ethiopia is 16.69 t ha^{-1} (CSA, 2022), which is lower than world average yield up to 20 t ha^{-1} (FAOSTAT, 2022). Moreover 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, respectively (FAO, 2023).

The attribute of low production of potato in Ethiopia is due to biotic and biotic factors. 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). Moreover, low levels of potato yields are associated with low soil fertility caused by low, unbalanced fertilizer application and poor agronomic practices (Alemayehu *et al.,* 2018). As plant density increases, there is a marked decrease in plant size and yield per plant. This effect is due to increased inter-plant competition for water, light and nutrients (Masarirambi *et al.,* 2012). The blanket recommended plant spacing for all potato varieties in Ethiopia is 75 cm by 30 cm between rows and plants, respectively (MoA, 2016). On the other hand, farmers in Ethiopia are using different spacing below or above the national recommendation many factors including lack of site specific recommended inter and intra row spacing (Arega *et al.,* 2018).

Apart from spacing, 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 (Alemayehu *et al.,* 2023). Potato is a high-yielding as well as heavy feeder crop, thus requiring balanced plant nutrients for proper growth and development. Ethio-SIS (2016) 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. Since the composition of these newly introduced fertilizers differs from that of DAP, the appropriate rate is not determined for potato production in the study area. In the past farmers use DAP and Urea as blanket recommendation. Shunka al et (2021) indicated that blanket application might have led to the depletion essential elements and consequently not satisfies the nutrient requirements of crops including potato. Accordingly, blended fertilizers, such as NPSB (18.9% N, 37.7% P_2O5, 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 (EthioSIS, 2014). 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.Therefor, 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 theses 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.

Materials and Methods

Description of the Study Area

The experiment was conducted on two 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 18^0c and 21^0c, respectively.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 adapt in altitude rage of 1600-2800 120 altitude. Belete is high yielding under research (26.24 t ha^{-1}) (Abdeta *et al.,* 2022). Blended NPSB (18.9% N, 37.7% P2O5, 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^{-1}) with one control. The experiment was laid out in a randomized complete block design (RCBD) in a factorial arrangement replicated three times. Each experimental unit had 4.55m length and 3m width with a total net area of 13.65m^2 each experimental unit length is divided into 7, 6 and 5 rows at 65cm, 75cm and 85cm intervals, respectively. The details of treatment combinations and their nutrient contents are shown in (Table 1).

Experimental Procedures and Crop Management

The experimental field was plowed three times at different time intervals starting from the end of May and leveled manually before field layout. NPSB fertilizer was applied at different rates at planting time while urea was applied in split application, at planting time and the remaining urea fertilizer was top dressed at 40 days after planting.100 kg ha^{-1} 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. All other non-treatment management practices were applied as per recommendation for the variety to all experimental plots.

Data Collection and Measurements

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 (Lung`aho *et al.,* 2007). 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 were free of diseases, insect pest damages and above 25g in weight were considered as marketable tubers as indicated by Lung'aho *et al.,* (2007). 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 were diseased and insect pest attacked and less than 25g, misshaped and decayed are considered as unmarketable tuber as indicated by Lung'aho *et al.,* (2007). Average tuber weight was recorded by dividing total fresh weight of tubers by the total number of fresh tubers per plot (Govinden, 2006 and Burga *et al.,* 2013). Agronomic efficiency was calculated in units of yield increase per unit of nutrient applied. Agronomic Efficiency (AE): It is described as the economic production obtained per unit of Fertilizer applied and was calculated as: $AE = \frac{YF-Y0}{F}$ (Kg kg^{-1}) Where, YF is the grain yield of a fertilized plot (kg ha^{-1}), Y0 is the grain yield of the control plot (kg ha^{-1}), and F is the amount of NPSB or applied (kg ha^{-}).

Soil Sampling and Analysis

A pre-planting and post-harvest composite 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 (Dewis and Freitas, 1984). 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 and Black (1934) whereas kjeldahl procedure was used for the determination of total N as described by Jackson (1958). The available P was measured by Bray II method (Bray and Kurtz, 1945).

Data Analysis

All the measured datas 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 (SAS, 2014) by SAS version 9.2) The data collected were statistically analyzed using the Analysis of Variance (ANOVA) procedures (Gomez and Gomez, 1984). Means were separated using the LSD test to signify the treatment differences at a 5% level of probability (Steel and Torrie, 1997).

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^{-1}) for potato and the official prices of blended and urea fertilizer was used for analysis. Labor costs were involved for application of blended NPSB fertilizer rates was recorded and used for analysis. The net returns (benefits) and other economic analysis were based on the formula developed by CIMMYT methodology (CIMMYT, 1988).

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 (1991). The organic carbon content of the soil is 4.58% which is medium according to the rating of Landon (1991). 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 (2014) 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^{-1}) of the experimental site was very low according to rating of Bray (1945). 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-1 which classified as medium (Landon, 1991). Medium CEC of the soil might be due to moderate organic matter content and high soil acidity.

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). On the other hand, the interaction effects of the NPSB application and inter row spacing showed non-significant variation in all parameters like Plant height, Number of main stem, Number of tuber, Marketable tuber, unmarketable tuber, total tuber yield and average tuber weight.

Plant height (cm)

The main 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 3). Plant height was increased with increasing rates of NPSB fertilizer. The highest plant height (87.33) was recorded from application of 200 kg NPSB ha^{-1} whereas the lowest plant height (78.27 cm) was recorded from control plot (Table 4). There is a significant and linear increase in plant height in response to increasing the rate of NPSB fertilizer rates and this may be attributed to the critical role of phosphorus, nitrogen, sulfur, and boron which plays in enhancing cell division, growth, and stem elongation to meet the demand for the increased plant height (Mamiru and Geleto, 2022).

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. This result has supported by the finding of Arega *et al.,* (2018); Getaneh and 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 ($P < 0.05$) on the number of main stem per hill. However, the interaction effect of NPSB fertilizer rate and inter-row spacing showed non-significant influence on the number of main stem (Table 3). Increasing the rate of the fertilizer application from 0 to 200 kg NPSB ha^{-1} increased the number of main stems per hill (Table 4).The highest main stem number (10.01 $hill^{-1}$) was obtained from the application of 200 kg ha^{-1} NPSB fertilizer while the shortest main stem number (5.19 $hill^{-1}$) 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 the increased number of main stem with increasing rates of NPSB fertilizer 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; Muluneh (2018) reported that the highest number of the stem (6.48) was recorded at rates of 350 kg ha^{-1} NPSB. 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; Kifle *et al.,* 2017; Harnet *et al.,* 2014).

Tuber Number $Hill^{-1}$

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^{-1} while the lowest tuber number (12.78) was recorded from control plot. Increasing NPSB application from 0 to 200 kg ha^{-1} 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. In agreement with the present finding, the authors of Getaneh and Laekemariam (2021); Tadesse and Mulugeta (2023) reported a significant tuber number increment in response to NPS fertilizer application. Besides, Burtukan (2016) and Bruk (2018) 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 $ha^{-1.}$ 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). Similar findings were reported Taye (2021) and Masarirambi *et al.,* (2012) planting potato at the wider spacing resulted in the production of higher numbers of marketable tubers/hill than the narrower spacing. Moreover, Tesfa (2012) 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^{-1})

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 t ha^{-1}) were obtained from the application of 200 kg ha-1 of NPSB fertilizer rate. While the lowest marketable tuber number (22.83 t ha -1) was recorded from the control plot (Table 5).

Increasing NPSB application from 0 to 200 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 t ha -1) was recorded from 85cm inter row spacing while the lowest marketable tuber yield (39.65) was recorded from 65 cm inter row 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.

The similar report was from Fayera *et al.,* (2015) that the highest marketable tuber yield (3.73 kg/plot) and the lowest unmarketable tuber yield (0.97 kg/plot) were obtained from combination of 150 kgha-1 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 (2007) 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 (Desalegn *et al.,* 2016) 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 (t ha^{-1})

The result showed that 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 t ha) was recorded at narrow inter-row spacing (65 cm) and the lowest (6.03 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. 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 (Tesfa, 2012; Tesfaye *et al.,* 2012). This result is in agreement with the findings of Tadele *et al.,* (2013) who stated that 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.

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 5).The difference in total tuber yield between the application rate of NPSB exhibited a significant increment on total tuber yield of potato plant. 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). In agreement with the present result, Minwyelet *et al.,* (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 (17.32t ha-1). Similarly, Fayera *et al.,* (2017) and Zabihi *et al.,* (2010) also reported that the highest total yield obtained from application of high nitrogen rate and at the closest spacing 10 cm intra row spacing. This result is in agreement with the finding of Muhammad *et al.,* (2015); Amasis (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.

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 (2023) who reported the highest average tuber weight from the effect of wider spacing. Nigusie (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.,* (2019) 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, Israel *et al.,* (2012); Zelalem *et al.,* (2009) and Husna and Kisetu (2014) who reported that the heavier average tuber weight were obtained from the increased application of NP fertilizer.

Table.1 Treatments combination for effect of NPSB and Inter row spacing for Potato crop

Trt	Rates NPSB (Kg/ha)	NPSB fertilizer composition (kg/ha)				Inter row spacing	Combination
		N	P_2O_5	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

Table.2 Selected soil physico-chemical properties before planting of experimental sites during 2022-2023

	Gechi district		Chora district			
	2022	2023	2022	2023		
Soil Characteristics						
Textural class	Clay	Clay	Clay	Clay	Value	(Bouyoucos, 1962)
pH	5.21	5.16	5.45	5.24	Strongly Acidic	(Tekalign, 1991)
OC	4.55	3.73	5.07	4.58	Medium	(Tekalign, 1991)
Total N (%)	0.39	0.29	0.44	0.34	Medium	(Ethio SIS, 2014)
Av P	0.76	0.61	0.71	0.88	very low	(Bray and kurttz, 1945)
CEC	22.33	18.67	24.63	23.51	Medium	(Landon *et al.,* 1991)

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

Table.3 Mean squares of ANOVA for phenological, and growth of potato as influenced by NPSB rates and inter-row spacing

Sv	DF	PH	SN	NT	MY	UMY	TY	AVTY
Rep	2	23.04ns	10.61ns	66.33ns	626.07ns	11.93ns	712.95ns	2.24ns
NPSB	3	105.44*	69.61*	435.06**	24357.94**	224.48**	29088.21***	3736.42**
IRS	2	40.02*	4.57*	28.58**	3701.25**	32.39**	4404.45**	516.15**
Loc	1	2.35ns	0.51ns	141.68**	10519871.67**	97503.07**	12642931.27**	2156.056**
NPSB*IRS	6	19.55ns	0.26ns	1.62ns	53.99ns	9.66**	542.80ns	26.08ns
Loc*NPSB	3	0.162ns	0.50ns	1.34ns	997966.92ns	272.63ns	108198.05ns	5.240ns
Loc*IRS	2	0.26ns	0.011ns	0.014ns	14885.63ns	39.34ns	16407.53ns	0.93ns
Error	136	52.29	1.68	10.48	321.71	20.73	339.25	49.13

Key: SV= Source, Loc=Location, DF= Degree freedom IRS, DM=Days to Maturity, PH = Plant Height, SN=Stem Number , TN = Tuber Number, TN= Number of tuber, MY=Marketable tuber yield ,UMY=Un Marketable tuber yield, TY=Tuber yield, AVTW=Average tuber weight, *= significant,=Highly Significant =NS-Non significant**

Table.4 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-1)		
0	78.27^{b}	5.19^{d}
50	78.67^{b}	6.65^{d}
100	80.11^{b}	7.474^{c}
150	84.67^{a}	8.87^{b}
200	87.33^{a}	10.01^{a}
Lsd (0.05)	4.08	0.68
Inter row spacing (cm)		
65	83.55^{a}	4.54^{c}
75	81.22^{b}	6.87^{b}
85	80.57^{b}	10.21^{a}
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

Table.5 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	12.78^{e}	22.83^{e}	7.22^{a}	24.33^{e}	69.66^{e}	30Mr
50	17.90^{d}	32.45^{d}	6.39^{b}	37.74^{d}	77.13^{d}	30Mr
100	21.44^{c}	40.10^{c}	6.25^{b}	46.26^{c}	88.65^{c}	30Mr
150	24.22^{b}	46.67^{b}	5.28^{c}	53.06^{b}	95.19^{b}	30Mr
200	26.88^{a}	51.36^{a}	1.5^{d}	58.57^{a}	100.84^{a}	30Mr
LSD (0.05)	1.51	2.64	0.21	2.72	3.26	
P-Value	**	**	**	**	**	
Inter row Spacing						
65	21.63^{b}	39.65^{b}	6.56^{a}	45.70^{c}	86.88^{b}	30Mr
75	22.33^{ab}	43.06^{a}	6.25^{b}	49.31^{b}	91.16^{a}	30Mr
85	23.16^{a}	45.16^{a}	6.03^{c}	51.72^{a}	93.32^{a}	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

Table.6 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
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

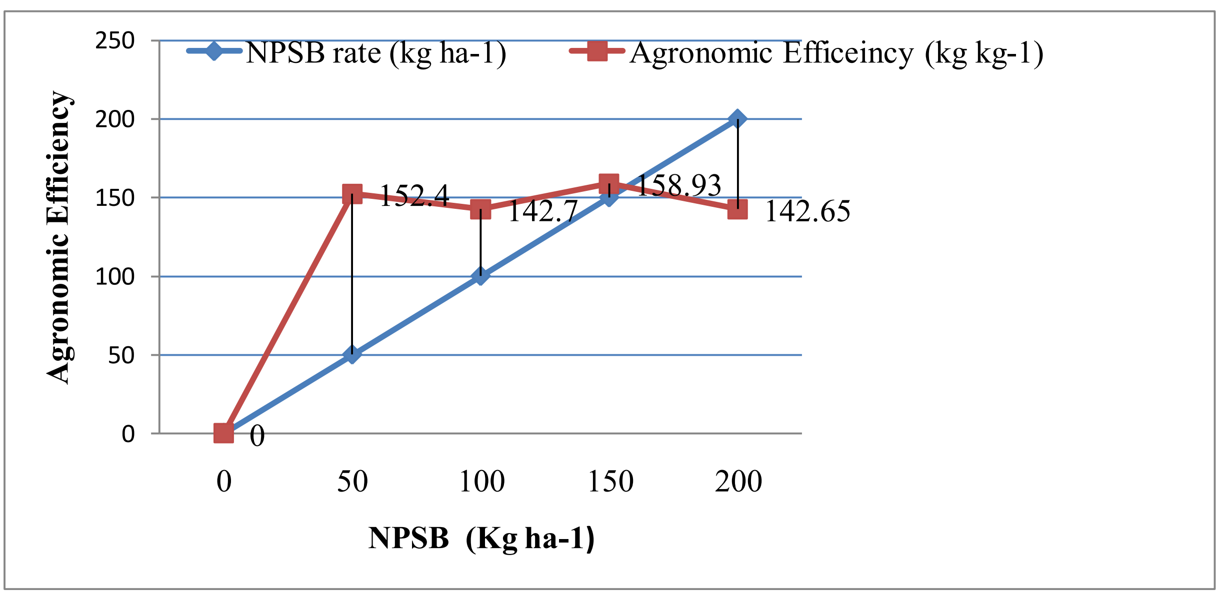
PH = Plant height; NMS = Number of main stem; NT= Number of tuber; MT= Marketable tuber; UMT= Unmarketable tuber; TTY= Total tuber Tuber yield ; AVTW = Average tuber weighte, * Very highly significant, ** =highly significant and ns=non significant**

Table.7 Result of economic analysis for response of Potato tuber yield to NPSB fertilizer rates and Inter row spacing

NPSB rate (kg ha^{-1})	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-1, GB = Gross Benefit, TVC = Total Variable Cost, NB= Net Benefit and MRR= Marginal Rate of Return

Figure.1 Effect of NPSB Agronomic Efficiency



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. This result is also in agreement with Bikila *et al.,* (2014) 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 5) reactions to the disease.

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} (Figure 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 (2018) 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.,* (2023) 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.

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*). Likewise, number of main stem highly significantly strong correlated with number of tuber (r=0.99***), Marketable yield (r=0.48**) and total tuber number (r=0.48**).

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 yield (r=0.48**) and Average tuber weight (r=0.39**). Similarly, Marketable tuber yield was strongly correlated with tuber number (r=0.49**), total tuber yield (r=0.99***) and Average tuber weight (r=0.92***) (Table 6).

Partial budget Analysis

The partial budget analysis revealed that the maximum net benefit of Birr 1231355 ha^{-1} with marginal rate of returns (MRR) of 3823.92% was estimated for plants that received 150 kg ha^{-1} blended NPSB fertilizer. The lowest net benefit of Birr 604995ha-1 was obtained from plants that did not receive blended NPSB fertilizer and inter row spaced at 65 cm612730 intra-row spacing (Table 10).

Furthermore, compared to other inter row spacing the highest net benefit (2120240-birr ha^{-1}) with an acceptable marginal rate of return (11444.83%) was obtained when 85cm inter row spacing was used (Tables 7). While the lowest net benefit of Birr 12730 ha^{-1} was obtained from inter row spaced at 65 (Table 7).

Conclusion

Understanding Fertilizer recommendation and inter row spacing of a given area has vital role in enhancing crop production and productivity on sustainable basis. Thus, agronomic and economic responses of potato under varying inter-row spacing and NPSB fertilizer rates were studied Buno Beadle 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^{-1} resulted maximum marketable tuber yield (51.36t ha^{-1}) and total tuber yield (58.57 t ha^{-1}) while lower yield were obtained from control treatment. Furthermore, the highest marketable tuber yield (45.16 t ha^{-1}) and total tuber yield (51.72t ha^{-1}) 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^{-1}) demonstrated the highest agronomic nitrogen use efficiency. The partial budget analysis revealed that the highest net benefit obtained (1231355 birr ha^{-1}) with acceptable marginal rate of return (3823.92%) and (2120240 birr ha^{-1}) with acceptable marginal rate of return (11444.83%) from NPSB kg ha^{-1} 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^{-1}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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