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Effects of Blended NPSB Fertilizer Rates on Growth, Yield and Yield Components of Potato (*Solanum tuberosum* L.) Varieties in Miserak Badawacho District, Hadiya Zone, Southern Ethiopia

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ABSTRACT

Background: Macro and micronutrients are the most limiting factors in the production of potato in most part of the country. Therefore, this study was conducted to determine the effect of blended NPSB fertilizer rates on yield and yield components of potato varieties in Hadiya zone, Southern Ethiopia in 2021-2022 cropping season.

Methods: The experiment was conducted as a factorial combination of five levels of blended NPSB fertilizer rates (0, 100, 150, 200, 250 kg ha^{-1}) and four potato varieties in randomized complete block design (RCBD) with three replications. Data collected on growth, yield and yield-related traits were subjected to analysis of variance.

Result: The results of the study revealed that variety and blended NPSB fertilizer showed a significant effect on crop phenology, growth, tuber yield and yield components. The interaction effect of variety and blended NPSB fertilizer also showed a significant effect on most of the traits measured except for days to 50% flowering and unmarketable tuber yield. The variety Belete showed the highest marketable tuber yield and total tuber yield with the application of 200 kg ha^{-1} NPSB fertilizer rate followed by variety Gudene). In terms of economic performance, 150 kg ha^{-1} NPSB fertilizer was found to show the marginal rate of return acceptable net benefit in variety Belete. Therefore, potato-growing farmers are advised to apply 150 kg ha^{-1} of NPSB fertilizer to grow Belete variety. In addition, Gudene variety at 250 kg ha^{-1} NPSB fertilizer application rate was found to show the highest marginal rate of return and net benefit can be considered as an alternative recommendation to increase the productivity of potato in the study area.

Key words: NPSB, Phenology, Potato, Yield.

INTRODUCTION

Potato is one of the most important cold-season vegetable crops consumed worldwide. It is considered as an inexpensive and nutritive food security crop, as it produces more dry matter, protein and calories per unit area and time than the major cereal crops (Rai and Yadav, 2005). In Ethiopia, potato ranks first among the major tuber crop in the volume of production and consumption followed by enset, sweet potato, yam and taro (Olango, 2008). Potato is the fourth most important food crop next to rice, wheat and maize and has a great contribution to food and nutrition security in the world (FAOSTAT, 2016). The annual production of the world and Africa in the year 2018 was about 368.2 and 26 million tons, respectively (FAO, 2020). Potato production in Ethiopia reached about 76,677.64 ha with a yield of 13.62 t/ha, in 2019 cropping season and it was 70362.22 ha with productivity of 13.13 t/ha in 2020 cropping season (CSA, 2020). This trend showed that there is a reduction in productivity of potato in the two cropping seasons mainly due to soil fertility and crop variety problem. Similarly Biruk (2018) reported that, about 1162.9 ha of land in the Badwacho district, Southern Ethiopia was covered by potato with average productivity of 9 t ha^{-1} under rain-fed conditions in 2017/2018, which is very low compared to world productivity (19.5 t ha^{-1}) and the national average yield (13.5 t ha^{-1}) of potato.

Low nutrient availability is one of the major limiting factors for productivity of potato. Naturally, potato is heavy feeder of nutrient that requires a large amount of organic and inorganic nutrients, predominantly nitrogen, phosphorous and potassium (NPK) (Atanaw and Israel, 2021). From these nutrients, phosphorus considered one of the required elements for the whole function of plants, especially for tuber formation, dry matter accumulation and hardening of potato stalks (Aarakit, 2021). N fertilization has been reported to increase the average fresh tuber, plant height, leaf number and tuber weight per plant (Kandil, 2011). Sulfur is one of the 16 essential nutrient elements and the fourth major nutrient after NPK, required by plants for proper growth and yield as it has known to take part in many reactions in all living cells (Sud and Sharma, 2002). A steady

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and prolonged supply of Boron throughout their growing period is necessary for potato where translocation of photosynthates from source to sink is needed for a longer period (Sarkar *et al*., 2007). The increase in total tuber yield in response to the increased application of the combined NPSB fertilizers is associated with the increased photosynthetic activity and translocation of photosynthetic product to the root, which might have helped in the initiation of more stolen on potato (Karenlampi and White, 2009). Therefore, the efficient usage of these nutrients is crucial to improve productivity.

Ethiopian soils are very diverse in terms of inherent and dynamic soil quality (Zelleke *et al*., 2019). Therefore, fertilizer recommendations made based on preliminary studies across diverse agro-ecologies in the country are crucial. Economically feasible fertilizer amount varies with soil type, fertility status, moisture amount, climatic variables, crop variety, crop rotation and crop management practices (Woldegiorgis *et al*., 2013). However, Ethiopian farmers rely on only two fertilizer types (UREA and DAP) to supplement the nutrient requirement of the crops. Farmers in the study area use blanket application without considering the fertility status of the soil, the environment and the type of varieties. The Ethiopian agricultural Institution (EIAR), recommends farmers generally to use a rate of 195 kg ha^{-1} of di-ammonium phosphate (DAP) and 165 kg ha^{-1} of urea, which sums up to account for 111 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1} to satisfy the phosphorous and nitrogen requirements of potato, respectively (Tewodros, 2014). However, studies revealed that the Ethiopian soils lack most of the macro and micronutrients that are required to sustain optimal growth and development of crops (Shiferaw, 2014).

Consequently, the yield and productivity of crops including potato in Ethiopia are much lower than in other countries. Recently ministry of agriculture (MoA) introduced a new brand of NPSB blended fertilizer having a proportion of 19% N, 38% P_2O_5, 7% S and B 0.1%, substituting DAP (MoA, 2013). This blended fertilizer has been currently distributed in the Ethiopian crop production system (MoA, 2013). Based on the soil fertility map, 13 blended fertilizers containing N, P, K, S, B, Zn and Cu in different blends have been recommended for the region (Ethiosis, 2014). In this regard, limited information on soil fertility studies for potato production and soil nutrient management practices in the study area are the major problems. Therefore, a study on the response of potato varieties to different rates of NPSB fertilizers under this specific agro-ecology is required to come up with optimum fertilizer recommendations. This study was, therefore, undertaken to investigate the rates of blended NPSB fertilizer effect on productivity of potato varieties in the rainy season in Southern Ethiopia.

MATERIALS AND METHODS

The experiment was conducted in the Miserak Badawacho district at Wera gera Kebele, Hadiya Zone, Southern Ethiopia in the 2021/2022 main cropping season. The area is geographically located at 7°14′00″N latitude and 37°95′00″E longitude with an altitude range of 1966 meters above sea level. It receives a mean annual rainfall of 1800 mm with a mean maximum temperature of 16-24°C and a minimum of 16°C (Fig 1).

Three potato varieties (Gudene, Belete and Jalene) collected from Holeta Agricultural Research centre, Ethiopia and one local check from the district were used for the experiment. The growing conditions and detail descriptions of each of the varieties are explained in Table 1. The varieties were selected based on their adaptation, better performance and disease resistance in the area. NPSB blended fertilizer with nutritional composition of 19% Nitrogen, 38% P_2O_5, 7% Sulfur and 0. 1% Boron was used in the study.

The four potato varieties (Gudene, Jalene, Belete and local) and five rates of blended NPSB fertilizer (0, 100, 150,

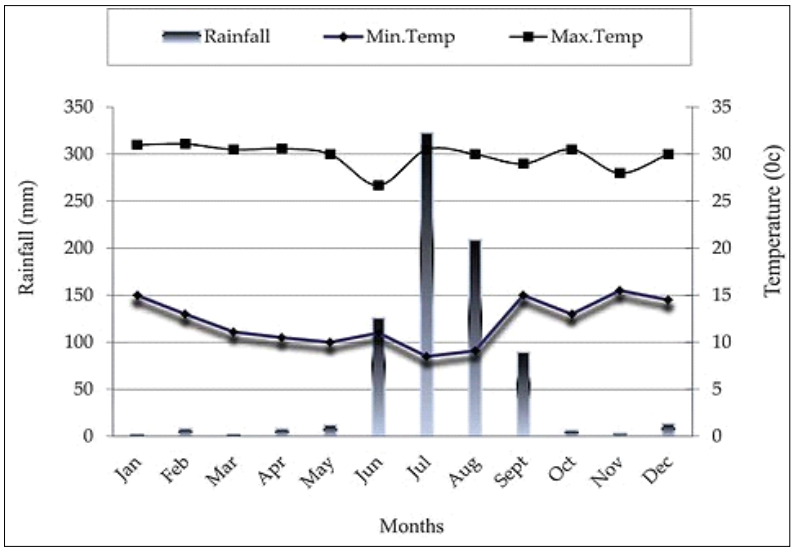


Fig 1: Observed annual cycle of climatology description of the study area.

200 and 250 kg ha^{-1}) were calculated on the basis of the N and P_2O_5 fertilizer application rates of recommendation for potato production in the area which is 195 kg ha^{-1} Diammonium Phosphate (DAP) and 165 kg ha^{-1} urea (Biruk, 2018). The experiment was conducted using a randomized complete block design (RCBD) in factorial arrangements with three replications. Each plot was arranged with 3 meters wide and 3 meters long and 1 m between blocks. Then the plots were divided into 4 rows having 10 plants per row. Medium-sized, healthy and well-sprouted potato tubers were planted at the spacing of 30 × 75 cm accommodating a total population of 40 plants per plot. Plants in the two outer rows, as well as those at both ends of each row were not considered for data collection to avoid border effects. The treatment combinations (Table 2) were formed following the proportion of NPSB percent distribution 19% N, 38% P_2O_5, 7% S and 0.1% B, respectively as described by (Ethiosis, 2014).

Data on different growth and yield components were recorded on sampled plants and plot basis. Days to 90% flowering at 50-60 days after planting (DAP), Days to maturity at 90-105 DAP, Plant height (cm) at 70 DAP, Number of leaves per plants at 70 DAP, Main stems number per plant at 70 DAP were collected from 10 representative plants per plot. The remaining parameters like marketable tuber number per hill, unmarketable tuber number per plant, total tuber number per hill, unmarketable tuber yield (t ha^{-1}) and total tuber yield (t ha^{-1}) were measured and calculated at 100-110 DAP. The averages of 10 plants were used for statistical analysis for each parameter. All the data collected were subjected to analysis of variance (ANOVA) procedure using GenStat 16th edition software (GenStat, 2014). Comparisons among treatment mean with a significant difference for measured characters were done by using Fisher's protected least significant difference (LSD) test at a 5% level of significance.

The economic analysis was carried out by using the methodology described by CIMMYT (1988) in which prevailing market prices for inputs at planting and outputs at harvesting were used. All costs and benefits were calculated on a hectare basis in Birr. The concepts used in the partial budget analysis were the mean tuber yield of each treatment, the gross benefit (GB) per hectare (the mean yield for each treatment) and the field price of fertilizers (the costs of NPSB, tuber seed and the application costs).

Table 1: List of potato varieties used in the experiment.

Variety	Accession code	Year of release	Altitude (m.a.s.l)	Days to maturity
Belete	CIP-393371.58	2009	1600-2800	110-120
Gudene	CIP-393371.58	2006	1600-2800	110-120
Jalene	CIP-384321.19	2002	1600-2800	110-120
Local	-	-	1500-2900	90-100

Source: (MOANR, 2016) *HARC= Holetta Agricultural Research Centre.

Table 2: The combination of fertilizer of experimental treatments and potato varieties.

Varieties	Treatment combination	Elemental composition			
		N	P_2O_5	S	B
Gudene	0 kg NPSB/ha + 0 kg urea/ha	0	0	0	0
Gudene	100 kg NPSB/ha +165 kg urea/ha	94.9	38	7	0.1
Gudene	150 kg NPSB/ha +165 kg urea/ha	104.4	57	10.5	0.15
Gudene	200 kg NPSB/ha +165 kg urea/ha	113.9	76	14	0.2
Gudene	250 kg NPSB/ha +165 kg urea/ha	123.4	95	17.5	0.25
Jalene	0 kg NPSB/ha + 0 kg urea/ha	0	0	0	0
Jalene	100 kg NPSB/ha +165 kg urea/ha	94.9	38	7	0.1
Jalene	150 kg NPSB/ha +165 kg urea/ha	104.4	57	10.5	0.15
Jalene	200 kg NPSB/ha +165 kg urea/ha	113.9	76	14	0.2
Jalene	250 kg NPSB/ha +165 kg urea/ha	123.4	95	17.5	0.25
Belete	0 kg NPSB/ha + 0 kg urea/ha	0	0	0	0
Belete	100 kg NPSB/ha +165 kg urea/ha	94.9	38	7	0.1
Belete	150 kg NPSB/ha +165 kg urea/ha	104.4	57	10.5	0.15
Belete	200 kg NPSB/ha +165 kg urea/ha	113.9	76	14	0.2
Belete	250 kg NPSB/ha +165 kg urea/ha	123.4	95	17.5	0.25
Local	0 kg NPSB/ha + 0 kg urea/ha	0	0	0	0
Local	100 kg NPSB/ha +165 kg urea/ha	94.9	38	7	0.1
Local	150 kg NPSB/ha +165 kg urea/ha	104.4	57	10.5	0.15
Local	200 kg NPSB/ha +165 kg urea/ha	113.9	76	14	0.2
Local	250 kg NPSB/ha +165 kg urea/ha	123.4	57	17.5	0.25

The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that varies (TCV) using the formula as described by CIMMYT (1988).

RESULTS AND DISCUSSION

The analysis of variance showed that days to 50% flowering and 90% maturity were significantly influenced by variety and blended NPSB fertilizer rates. Similarly, the interaction effect of variety × NPSB fertilizer rates were significantly ($P<0.05$) and highly significantly ($P<0.001$) affected the days to 50% flowering and days to 90% maturity, respectively (Appendix Table 1). All the tested varieties of potato in the plots that did not receive fertilizer (control plot) and 100 kg ha^{-1} NPSB fertilizer showed earliness to maturity, these could be related to the characteristics of most plants that produces flower under stress condition to perpetuate themselves. On the other hand, potato varieties in all other plots that received (200 and 250 kg ha^{-1} NPSB) blended fertilizer rates showed delayed 90% maturity (Table 3). The differences in the days to 50% flowering and days to 90% maturity among the varieties can be due to their genetic variability in response to the different application rates of blended NPSB fertilizer. Mekonnen (2019) also reported that delayed days to 50% flowering and 90% maturity in plants were increased with increased blended NPSB fertilizer rates. The increment in days to 50% flower initiation and 90% of physiological maturity, with the increasing application of blended fertilizer, this might be attributed to the positive effect of nitrogen that stimulated growth and prolonged vegetative phase (Khan *et al.*, 2009). Similarly, Biruk (2018) also reported that increasing NPSB application from 0 to 200 kg ha^{-1} prolonged the days to 50% flowering and 90% maturity of plants by two and three days, respectively compared to the control plots. The result also in agreement with Sharma *et al.* (2015) and Belachew (2016), who reported that the application of NPSB fertilizer delayed the flowering stage.

Plant height and number of the main stem

Plant height and number of main stems/hills were significantly affected by variety and blended NPSB fertilizer rates. The interaction of variety × NPSB fertilizer had also a significant effect on these traits (Appendix Table1). Variety Belete had significantly highest number of main stems/hills and tallest plant height with application of 250 kg h^{-1} NPSB fertilizer rates (Table 4). Gudene variety also had a significantly higher number of main stems/hills than the local did and Jalene varieties on the same level 250 kg ha^{-1} NPSB fertilizer rates (Table 4), this demonstrates that potato varieties had differential response to the applied NPSB fertilizer rates. The variety Gudene gave the highest (84.4 cm) plant height at 250 kg NPSB ha^{-1} fertilizer application rates, followed by Belete (82.27) on the same level of NPSB. The increase in plant height in relation to increased application of NPSB fertilizer rates may be attributed to the influence of the nutrients contained on enhancing plant growth owing to their contribution to enhanced cell division and stem elongation promoting leaf expansion and vegetative growth

Appendix Table 1: Mean square of growth, yield and yield components of potato varieties as influenced by NPSB fertilizer rate at Mera Gera kebele 2021 cropping season.

SOV	DF	D 50% F	DM	PH (cm)	NMS	LN	ATN	ATW	MTN	UMTN	MTY	TTY
Rep	2	0.15	0.19	36.09	0.07	46.08	0.24	13.86	0.47	0.11	2.73	1.84
NPSB fer	4	8.39**	9.09**	565.17**	8.37**	27665.43**	42.38**	335.33**	38.87**	0.12^{ns}	481.61**	540.86**
Variety	3	2.99**	209.18**	2114.14**	14.29**	11940.26**	117.01**	3803.85**	112.68**	0.71**	2207.89**	2446.22**
NPSB*Variety	12	0.45*	1.18**	38.73**	1.16**	819.57**	6.54**	14.47**	6.34**	0.12^{ns}	68.61**	73.11**
Error	38	0.21	0.2	0.1996	0.09	17.94	0.23	13.91	0.42	0.17	2.44	2.267
CV (%)		0.9	0.4	4.1	6.3	1.6	5.8	7.2	8.7	39.8	8.2	7.2

*, ** and ns probability level at 5%, 1% and non-significant, respectively. D 50% F= Days to 50% flowering; DM= Days to 90% maturity, PH= Plant height (cm), NMS= Number of main stem hill^{-1}, LN= Leaf number hill^{-1}, ATN= Average tuber number hill^{-1}, ATW= Average tuber weight (g/tuber), MTN= Marketable tuber number hill^{-1}, UMTN= Unmarketable tuner number hill^{-1}, MTY= Marketable tuber yield (t ha^{-1}), UMTY= Unmarketable tuber yield (t ha^{-1}), TTY= Total tuber yield (t ha^{-1}).

of plants. According to Mekonnen (2019) the tallest plants (67.13 cm) were recorded in plots that received 300 kg ha^{-1} NPSB fertilizer which was statically at par with 250 kg ha^{-1} NPSB fertilizer, while variety Belete attained shortest plant height (54.21 cm) in plots which received 0 NPSB fertilizer.

Gudene and Belete varieties also attained the highest main stem number (6.8 and 7.7 $hill^{-1}$, respectively) from 250 kg ha^{-1} NPSB fertilizer application rates while the shortest plants (37.8 cm) and lowest main stem number (3.13 $hill^{-1}$) were registered at the local variety in the unfertilized plot (Table 4). This indicated that low rate of fertilizer application retarded plant height and reduced potato plant in production of more stem. Increasing the rate of NPSB fertilizer increased plant height and main stem number per hill linearly in all the four varieties. Increasing the rate of the fertilizer application from 0 to 250 kg NPSB ha^{-1} increased the plant height and main stems number per hill (Table 5). Nitrogen uptake by plant roots from the soil might sufficiently enhanced vegetative growth. Moreover, Belachew (2016) reported that plant height is increased with increasing application of NPSB fertilizer from 0 to 350 kg ha^{-1}. Similarly, Habtamu *et al*. (2016) demonstrated that increasing the rate of phosphorus from nil to 230 kg P_2O_5 ha^{-1} resulted in highly significant increase in plant height.

Table 3: Interaction effect of blended NPSB fertilizer and potato varieties on days to 50% flowering and 90% maturity at Miserak Badawacho district during the 2022 cropping season.

NPSB (kg/ha)	Gudene	Belete	Jalene	Local
		Days to 50% flowering		
0	52.7±0.1^{bcd}	51.9±0.3^{a}	53.2±0.2^{cdefg}	51.9±0.1^{a}
100	53.1±0.1^{bcde}	52.6±0.1^{b}	53.5±0.3^{efghi}	52.7±0.2^{bc}
150	53.1±0.1^{bcde}	53.0±0.1^{bcde}	53.7±0.2^{fhij}	53.1±0.2^{bcde}
200	53.5±0.5^{efghij}	53.1±0.2^{bcde}	54.3±0.2^{k}	53.0±0.0^{bcde}
250	54.0±0^{ijk}	53.2±0.2^{cdef}	53.9±0.1^{ijk}	53.3±0.1^{defgh}
LSD (0.05)	0.5			
Mean	53.1			
CV (%)	0.9			
		Days to 90% maturity		
0	93.1±0.1^{g}	99.7±0.5^{de}	99.1±0.1^{e}	101.5±0.3^{c}
100	93.2±0.3^{g}	100.4±0.2^{d}	99.0±0.1^{e}	101.9±0.1^{abc}
150	93.8±0.1^{fg}	101.9±0.5^{abc}	99.9±0.5^{d}	101.7±0.3^{bc}
200	94.5±0.1^{f}	102.3±0.1^{abc}	101.5±0.3^{c}	101.5±0.2^{c}
250	94.4±0.1^{f}	102.7±0.2^{a}	102.0±0.0^{abc}	102.5±0.1^{ab}
LSD (0.05)	0.7			
Mean	99.3			
CV (%)	0.4			

Mean values with standard error of the mean followed by the same letter(s) within columns did not show significant differences at a 5% probability level. LSD (5%) = Least significant difference at P<0.05.

Table 4: Interaction effect of blended NPSB fertilizer and potato variety on plant height (cm) and main stem number per hill at Miserak Badawacho district during the 2022 cropping season.

NPSB	Plant height (cm)				Main stem number			
(kg/ha)	Gudene	Belete	Jalene	Local	Gudene	Belete	Jalene	Local
0	60.7±1.0^{de}	60.6±1.3^{de}	50.1±1.9^{h}	37.8±2.5^{j}	4.1±0.2^{gh}	3.6±0^{hi}	4.3±0.2^{fg}	3.1±0.2^{i}
100	62.7±1.2^{cd}	62.7±1.5^{cd}	51.3±0.7^{h}	45.1±1.0^{i}	4.5±0.2^{fg}	4.5±0.1^{cd}	4.8±0.4^{ef}	3.7±0.1^{hi}
150	66.7±2.0^{c}	65.5±2.7^{c}	52.6±1.3^{gh}	44.3±1.2^{i}	5.7±0.2^{cd}	5.7±0.1^{cd}	5.2±0.2^{de}	3.5±0.1^{i}
200	76.6±1.0^{b}	74.7±1.7^{a}	57.1±1.2^{ef}	50.2±2.2^{h}	6.4±0.3^{b}	5.6±0.1^{cd}	5.6±0.1^{cd}	3.3±0.2^{i}
250	84.4±0.3^{a}	82.3±1.2^{b}	56.1±0.9^{fg}	52.8±1.9^{gh}	6.8±0.1^{ab}	5.8±0.2^{c}	5.7±0.1^{c}	3.7±0.1^{hi}
LSD (0.05)	4.0				0.51			
Mean	59.7				6.3			
CV (%)	4.1				4.9			

Means with standard error in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance; LSD (0.05) = Least significant difference at 5% level; CV = Coefficient of variation.

Number of leaves per hill

Number of potato leaf was highly significantly (P<0.001) influenced by rates of NPSB fertilizers and varieties. The interaction of variety × NPSB fertilizer had also a significant effect on the number of leaves (Appendix Table 1). The maximum number of leaf (342.9, 334.2, 314.6 and 272.5) on Gudene, Belete Jalene and local, respectively were recorded from plots with 250 kg ha^{-1} NPSB application followed by 200 and 150 kg ha^{-1} application rates, this could be due surplus application of blended fertilizer while the lowest number of leaves were recorded from unfertilized plot (Table 5). This result is in line with the report of Diriba and Tilaye (2020), who reported the maximum number of leaves from the plot received 200 kg ha^{-1} NPSB, followed by 150 and 100 kg ha^{-1} of NPSB application rates. Whereas, the lowest number of leaves was recorded from unfertilized plots followed by plots fertilized with 50 kg ha^{-1} Gudene variety.

Average tuber number per hill

Average number tubers were highly significantly (P<0.001) influenced by the rates of NPSB fertilizers and varieties. The interaction effect of blended NPSB fertilizer rates and variety also significantly influenced the average number tubers (Appendix Table 1). The average tuber number per hill increased with an increase blended NPSB fertilizer rates. The highest tuber number per hill 14.3, 12.8, 8.8 and 6.0 were obtained from Gudene, Belete, Jalene and local varieties, respectively at 250 kg NPSB ha^{-1} fertilizer application rate compared to the number of tubers per hill produced by those varieties at 0 kg of NPSB ha^{-1} (Table 6) demonstrating potato varieties showed high response to NPSB fertilizer.

The current results are similar to the findings of Habtamu *et al*. (2016), who reported that increasing the application of nitrogen and phosphorus increased the total tuber number per hill. The highest (9.00) average tuber number was recorded from Belete variety while the lowest (8.61) was recorded from variety Gudene with zero fertilizer application (Shunka, 2021). In their study, the highest (10.36/hill) average tuber number was recorded from variety Belete at 200 NPSB + 150 urea kg/ha treatment and the lowest (7.00/hill) average tuber number produced from Belete variety grown without fertilizers while Gudene provided the highest 10.83 average tuber number per hill at 300 NPSB + 150 urea kg/ha and the lowest (6.24) recorded at control treatment.

Table 5: Interaction effect of blended NPSB fertilizer rates and potato variety on leaf number at Miserak Badawacho district during the 2022 cropping season.

Blended NPSB	Average number of leaves per hill			
(kg ha^{-1})	Gudene	Belete	Jalene	Local
0	204.9±1.5^{j}	210.4±0.5^{j}	203.9±1.3^{j}	182.3±1.4^{k}
100	246.2±0.5^{h}	255.6±3.8^{g}	240.8±5.2^{h}	210.2±0.8^{j}
150	322.3±2.3^{d}	321.1±1.6^{de}	256.4±4.4^{g}	229.7±4.5^{i}
200	340.1±1.7^{ab}	329.9±1.4^{c}	274.6±3.5^{f}	268.4±2.7^{f}
250	342.9±1.6^{a}	334.2±1.3^{bc}	314.6±1.6^{e}	272.5±1.6^{f}
LSD (5%)	7.0			
Mean	268.1			
CV%	1.6			

Means with standard error in columns and rows followed by the same letter(s) are not significantly different at a 5% level of significance; LSD (0.05) = Least significant difference at a 5% level; CV = Coefficient of variation.

Table 6: Interaction effect of blended NPSB fertilizer and variety on average tuber number at Miserak Badawacho district during 2022 cropping season.

NPSB rates	Average tuber number per hill			
(kg ha^{-1})	Belete	Gudene	Jalene	Local
0	8.7±0.5^{ij}	5.5±0.2^{ef}	6.2±0.5^{hi}	4.2±0.4^{k}
100	9.7±0.1^{gh}	6.9±0.2 ^{d}	6.7±0.2^{h}	3.8±0.4^{k}
150	11.5±0.3^{bc}	12.0±0.3^{c}	6.5±0.1^{h}	5.1±0.1^{j}
200	12.3±0.2^{b}	12.3±0.2^{bc}	7.7±0.2^{fg}	5.1±0.2^{j}
250	12.8±0.1^{b}	14.3±0.3^{a}	8.8±0.3^{e}	6.0±0.2^{hi}
LSD (5%)	0.80			
Mean	8.32			
CV (%)	5.8			

Means with standard error in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance; LSD (0.05) = Least significant difference at 5% level; CV = Coefficient of variation.

Table 7: Interaction effects of blended NPSB fertilizer and potato variety on average tuber weight (g) at Miserak Badawacho district during 2022 cropping season.

NPSB rates	Average tuber weight (g)			
(kg ha^{-1})	Belete	Gudene	Jelene	Local
0	64.3±0.3^{b}	43.9±1.0^{fg}	35.8±3.4^{hi}	29.6±3.9^{i}
100	72.5±0.8^{a}	53.0±0.4^{de}	41.8±1.2^{fgh}	35.7±3.8^{hi}
150	74.3±0.3^{a}	55.6±0.6^{cd}	46.5±3.3^{ef}	38.6±2.5^{gh}
200	76.2±0.4^{a}	60.3±0.1^{bc}	48.6±1.3^{ef}	37.7±3.7^{gh}
250	76.0±0.6^{a}	64.5±1.0^{b}	46.6±0.4^{ef}	38.5±3.5^{gh}
LSD (5%)	6.17			
Mean	52.0			
CV%	7.20			

Mean values with standard error followed by the same letter(s) in columns and rows of each traits had nonsignificant differences at a 5% probability level. LSD (5%) = Least significant difference at P<0.05.

Table 8: Unmarketable tuber yield (t ha^{-1}) of potato varieties at Miserak Badawacho district during 2022 cropping season.

Varieties	Unmarketable tuber yield (t ha^{-1})
Gudene	2.9±0.3^{a}
Belete	2.7±0.4^{a}
Jalene	1.3±1.5^{b}
Local	1.6±0.2^{b}
CV %	39.1
LSD (5%)	0.69
Mean	2.1

Means with standard error in column followed by the same letter(s) are not significantly different at a 5% level of significance; LSD (0.05) = Least significant difference at a 5% level; CV = Coefficient of variation.

Average tuber weight (ATW) per hill

The ANOVA result revealed that ATW highly significantly (P<0.001) influenced by the rates of NPSB fertilizers and varieties. This trait was also influenced by the interaction effect of blended NPSB fertilizer rates and variety (Appendix Table 1). Increased rates of blended NPSB fertilizer increased average tuber weight for all varieties that can be associated with enhanced fertility allow tuber expansion. The highest tuber weights were recorded from Belete (76.00 g) and Gudene (64.5 g) and at a rate of 250 kg NPSB Kg ha^{-1} followed by Jalene variety (46.0 g) and the lowest was recorded at unfertilized plots and lower rates 0-100 kg NPSB Kg ha^{-1} all varieties (Table 7). These results demonstrated that high amount of NPSB fertilizer is important to attain greater tuber weight as potato is heavy feeder of nutrient. The highest ATW 0.98 kg/hill observed on fertilizer rate 150 NPSB + 250 urea kg/ha and the lowest ATW 0.61 kg/hill was reported in control plot. Similarly, Shunka (2021) reported that the highest (1.00 kg/hill) ATW was recorded from variety Belete while lowest 0.72 kg/hill ATW was recorded from variety Gudene. The finding of Mulubrhan (2004) also demonstrated that the application of N and P significantly increased average tuber weight (ATW). According to the report of Muluneh (2018) the increment of average tuber weight is obtained in response to the increased supply of blended NPSB fertilizer might be due to more fast growth, more foliage and increase in leaf area and higher supply of phosphorous-containing fertilizer, which may have induced formation of bigger tubers thereby resulting in higher average tuber weight. Boron does have a direct influence on yield or related attributes as it plays a great role in root development through which, it facilitates more nutrient-up take and more stolen development used to produce more tubers.

Unmarketable tuber yield (t ha^{-1})

The analysis of variance showed that the effect of rates of blended fertilizer was non-significant but variety had a significant effect (p<0.001) on unmarketable tuber yield of potato. This indicates the performance of variety is not dependent on the different application of blended NPSB fertilize for this trait. The heaviest unmarketable tuber yield (2.88 and 2.68 t ha^{-1}) was recorded from Gudene and Belete varieties, respectively (Table 8). Inconsistent with this result (Fantaw *et al*., 2019) stated that a minimum unmarketable tuber yield was recorded from the application of 55-9.87-25.4 kg ha^{-1} of blended NPS fertilizer ($N_2/S_2/P_2O_5$), while the maximum unmarketable yield was measured from unfertilized treatments in the Northern part of Ethiopia. However, the mean values of unmarketable tuber yields due to fertilizer types (NPS, NPSB and NPSZn) were not statistically different from each other (Diriba and Tilaye, 2020).

Marketable and total tuber yields (t ha^{-1})

The marketable tuber and total tuber yields were significantly affected by variety and blended NPSB fertilizer rates. The interaction of variety × NPSB fertilizer had also a significant effect (Appendix Table 1). Increasing blended NPSB fertilizer application generally increased marketable tuber yields and total tuber yields of the tested potato varieties. The highest marketable tuber yield and total tuber yields of the Belete variety (39.93 t ha^{-1} and 43.8 t ha^{-1}) were recorded at the rate of (250 kg NPSB ha^{-1}) fertilizer application, respectively (Table 9). However, the lowest marketable tuber yield and total tuber yield of (4.23 t ha^{-1} and 5.34 t ha^{-1}) were recorded

from unfertilized local variety plots respectively (Table 9), showing local varieties are also very responsive to inorganic fertilizer application. The increase in the yield of tubers with an increase in applied fertilizer was associated with increasing in the number of tubers in the medium and large categories at the expense of the small ones due to an increase in the weight of individual tubers (Sharma *et al*., 2015). The varieties exhibited differential yielding abilities in the study area. In general, Gudene and Belete varieties are best performing in this study. The varieties utilized applied fertilizer differently and this could be the reason for difference in marketable tuber yield.

Variety Belete showed the highest number of total tuber yield with 200 kg h^{-1} NPSB fertilizer application rates (Table 9). Gudene also had a significantly higher total tuber yields than the local and Jalene varieties on the same level 250 kg h^{-1} NPSB fertilizer rates. Increasing blended NPSB fertilizer application generally increased total tuber yields of the tested potato varieties. The highest total tuber yields of the Belete variety (43.8 t ha^{-1}) were recorded at the rate of 200 kg NPSB ha^{-1}

Table 9: Interaction effect of blended NPSB fertilizer and varieties on marketable tuber and total tuber yields t ha^{-1} of potato varieties at Miserak Badawacho district during 2022 cropping season.

NPSB	Marketable tuber yield (t ha^{-1})				Total tuber yield (t ha^{-1})			
(kg ha^{-1})	Gudene	Belete	Jalene	Local	Gudene	Belete	Jalene	Local
0	8.5±0.7^{i}	21.8±1.6^{e}	7.2±0.5^{i}	4.2±0.8^{j}	10.7±0.5^{hij}	23.0±1.4^{f}	8.4±0.7^{jk}	5.3±0.7^{l}
100	13.8±1.3^{gh}	28.6±1.1^{d}	11.4±1.0^{h}	4.6±0.2^{j}	16.4±0.4^{g}	32.3±0.7^{de}	12.5±0.9^{hi}	6.0±0.8^{kl}
150	27.6±1.4^{d}	38.3±1.2^{ab}	11.7±0.6^{h}	7.4±0.7^{i}	30.2±1.0^{e}	39.9±0.8^{c}	13.1±1.0^{h}	8.6±0.7^{j}
200	31.5±0.5^{c}	40.3±1.2^{a}	15.2±0.2^{fg}	7.4±0.8^{i}	33.8±1.4^{d}	43.8±1.4^{a}	16.6±0.2^{g}	9.9±1.1^{ij}
250	36.8±0.2^{b}	39.9±0.6^{a}	17.0±0.7^{f}	8.1±0.9^{i}	40.8±0.4^{bc}	43.3±0.4^{ab}	18.2±0.7^{g}	10.1±0.7^{ij}
CV (%)	8.2					7.1		
LSD (5%)	2.6					2.5		
Mean	19.1					21.1		

Means with standard error in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance; LSD (0.05) = Least significant difference at 5% level; CV = Coefficient of variation.

Table 10: Partial budget analysis of effects of blended NPSB fertilizer rates and variety on yield-related traits and tuber yield of potato Miserak Badawacho during 2022 cropping season.

Treatments NPSB (kg ha^{-1})	Variety	AMTY (t/ha)	AMTY (t ha^{-1})	TVC (ETB ha^{-1})	GB (ETB ha^{-1})	(ETB ha^{-1})	MRR (%)
0	Gudene	8.53	7.67	36,600	76,700	40,100	
100	Gudene	13.78	12.40	46,700	124,400	77,700	372.27
150	Gudene	27.57	24.81	48,900	248,100	199,200	5522.72
200	Gudene	31.46	28.31	49,120	283,100	233,980	1580.9
250	Gudene	36.79	33.04	51,320	330.400	279,080	2050
0	Belete	21.7	19.53	36,600	195,300	158,700	-
100	Belete	28.63	25.76	46,700	257,600	210,900	516.8
150	Belete	38.27	34.44	48,900	344,400	295,500	3845.4
200	Belete	40.33	36.29	49,120	362,900	313,780	840
250	Belete	39.99	36.00	51,320	360,000	308,680	D
0	Jalene	7.23	6.50	36,600	65,000	28,400	-
100	Jalene	11.43	10.28	46,700	102,800	56100	274.2
150	Jalene	11.73	10.55	48,900,	105,500	56600	22.72
200	Jalene	15.2	13.68	49,900	136,800	86,900	1377.27
250	Jalene	17.03	15.32	51320	153,200	101,880	680.9
0	Local	4.23	3.80	31,800	38,000	6200	-
100	Local	4.63	4.16	41,900	41,600	-300	D
150	Local	7.43	6.68	44,100	66,800	22700	1045.4
200	Local	7.43	6.68	46,300	66,800	20500	D
250	Local	8.13	7.3	48,500	73,000	24500	181.81

Where: Cost of fertilizer NPSB = 44 Birr kg^{-1}, Cost of tuber seed = 10 Birr kg^{-1}; Fertilizer application cost = 4400 Birr ha^{-1}, potato tuber local selling price = 10 Birr kg^{-1}, AMTY= Adjusted marketable tuber yield, TVC = Total variable cost, GB = Gross benefit, NB = Net benefit, MRR = Marginal rate of return, ETB = Ethiopian birr.

and Gudene variety (40.8 t ha^{-1}) at a rate of 250 kg NPSB ha^{-1} fertilizer application (Table 9). Similarly, the findings of Muluneh (2018) stated that the highest total tuber yield (41.19 t ha^{-1}) was recorded from 300 kg ha^{-1} NPSB applied on variety Belete which was statistically at par with variety Gudene; while the lowest total tuber yield (15.7 t ha^{-1}) was recorded from unfertilized plots from Jalene, Gudene and Belete varieties. Fikre (2018) reported that the increase in total tuber yield in response to the increased application of the combined NPSB fertilizers might be due to the increased photosynthetic activity and translocation of photosynthetic product to the root, which might have helped in the initiation of more stolen on potato.

In the interaction of variety and rates, Belete gave its maximum 51.16 t/ha tuber yield at 300 kg/ha NPSB + 150 kg/ha urea followed by 49.92 t/ha at 150 kg/ha NSB + 250 kg/ha urea while the lowest 33.26 t/ha tuber yield was recorded from control. Application of 250 NPSB + 150 urea kg/ha to Gudene triggered to produce maximum yield 39.09 kg/ha followed by 150 kg/ha NPSB + 250 kg/ha urea while the lowest yield 23.25 t/ha was obtained from control. Belete variety showed tuber yield increment from 33.26 to 51.16 t/ha as a result of increasing fertilizers from 0-300 NPSB + 150 urea kg/ha which is 54% while Gudene provided the tuber yield increase due to increasing fertilizers from 0 to150 kg/ha NPSB + 250 kg/ha urea (Shunka, 2021).

Economic analysis

According to CIMMYT (1988), the partial budget analysis included the total variable costs and net benefits of each treatment. In this study, the costs of fertilizer and cost for transporting and application varied, while other costs were constant for each treatment. Therefore, the fertilizer and labour-related costs, gross incomes, net benefit and associated net return are presented in Table 10. Overall benefits of the application of NPSB fertilizer on potato exceed no application both in yields and in net benefits. Application of 200 and 250 kg/ha NPSB fertilizer recorded the first and second highest net benefits, while application of 150 kg/ha NPSB fertilizer recorded the 3rd highest net benefit of potato. Overall, the highest marginal rate of return was obtained from the application of 150 kg/ha of the NPSB fertilizer rate (Table 10). Gudene was statistically at par with Belete whereas the lowest result for these parameters was recorded at Jalene and local varieties. In terms of economic performance, 150 kg/ha NPSB was found to show the highest marginal rate of return (5522.72%) with the Gudene variety. Therefore, potato-growing farmers are advised to use 150 NPSB kg ha^{-1} with Gudene variety followed by Belete variety with the same rate of NPSB fertilizer.

CONCLUSION

Agronomic and economic responses of potato under varying varieties and NPSB fertilizer rates were investigated in Wera farmer training center, Hadiya zone of Southern Ethiopia. The result revealed that effects of NPSB rates and Varieties significantly affected growth and yield parameters.

The result revealed that the different NPSB fertilizer application rates and varieties showed differential response on the growth, yield and yield related traits of potato. The highest marketable tuber yield (40.33 t ha^{-1}) and total tuber yield (43.80 t ha^{-1}) were recorded in Belete variety with application rate of 200 kg ha^{-1} NPSB fertilizer and the highest marketable tuber yield (36.8 t ha^{-1}) and total tuber yield (40.8 t ha^{-1}) were recorded in Gudene variety with application rate of 250 kg ha^{-1} NPSB fertilizer. In terms of economic feasibility, Gudene variety at 150 kg ha^{-1} NPSB fertilizer was found to show the highest marginal rate of return and net benefit. In addition, 150 kg ha^{-1} NPSB fertilizer for Belete variety showed a marginal rate of return with acceptable net benefit. Therefore, potato-growing farmers are advised to apply 150 kg ha^{-1} of NPSB fertilizer to grow Gudene variety and the same application rate for Belete variety can be considered as an alternative recommendation to increase the productivity of potato in the study area. Thus, it is recommended to conduct further studies by considering the Belete and Gudene potato varieties and different rate of NPSB fertilizer to make sound recommendations to enhance productivity of potato in the area.

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Conflict of interest

The authors declare there is no conflict of interest.

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