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Research Article

Effects of Blended NPSZnB Fertilizer Rates on Yield and Quality Traits of Potato (*Solanum tuberosum* L) at Assosa District

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Abstract

Potato is ranked third after rice and wheat in terms of consumption in the world, and first among root and tuber crops. However, the production is limited by several factors including low in soil fertility, lack of improved varieties, inappropriate spacing, and other poor agronomic management. The objective of the present study is to recognize the optimum rate of the blended NPSZnB and potassium fertilizers for profitable production of potato at Assosa area. The experiment was laid out in RCBD with arrangement of split plot in three replications. The main plot consisted of two potato varieties i.e. Belete and Gudane varieties. The subplot consisted of four levels of blended NPSZnB with potassium chloride rates, one recommended NPK (nitrogen, phosphorus and potassium) and unfertilized plot. The interaction effects of potato tuber size distribution and quality traits were not significantly (P>0.05) affected by different rates of NPSZnB with adjusted nitrogen, phosphorus and potassium chloride fertilizers and different potato varieties. Out of different potato varieties, Belete variety gave the highest yield as compared to Gudane variety. The highest total tuber yield and large sized tuber yield were obtained by the application of 200% NPSZnB (35.4N+70.6P_2O_5+15.2S+0.5B+4.4Zn) +138 kg K_2O ha^{-1}, with adjusted 184.6kg N+ 109.6kg P_2O_5 per ha therefore, we are tentatively recommended for beneficiaries at Assosa area.

Keywords

Potato Varieties, Interaction Effects, Fertilizers Rates

1. Introduction

Potato (*Solanum tuberosum* L.) is most important crop ranked third after rice and wheat in terms of consumption in the world, and first among root and tuber crops, followed by cassava, sweet potato and yams in production [1].

High nutrition (carbohydrates, protein, dietary fibre, vitamins, minerals, amino acids, etc.), easy digestibility, bulk quantity production, etc. have made potato the most popular root and tuber crop of the world [2]. A total of 374 million tons of potatoes were produced worldwide, with China (95.57 million tonnes) and India (56.17 million tons) the largest potato producer countries in 2022 [3].

Potato is a major part of the diet of half a billion consumers in the developing countries. It is an important food and cash crop in Eastern and Central Africa, playing a major role in national food security and nutrition, poverty alleviation, income generation, and provides employment in the production,

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processing and marketing sub-sectors [4]. Africa produced 17,625,680 tons (1,765,617 ha), and the potato yield in Ethiopia was projected to be 921,403.9 tons (66,423.33 ha), with an average yield of 13.76 tons ha, and the country's productivity on farmer's fields was lower than the average yield of experimental areas (38 tons ha) [5]. In addition, globally millions of people depend on potatoes. Potato is one of the tuber crop grown in Benishangul Gumuz region whereby the number of farmers growing potato is increasing from time to time in region [6]. The number of farmers growing potato in Benishangul Gumuz region was approximately 3,277 in 2015/16 and increased to 8,359 farmers in 2016/17 [7].

The decline in yield of potato is affected by a number of factors, including decline in soil fertility, use of low yielding varieties, size of the tuber, planting space, poor agronomic management practices, and poor climatic conditions [8]. In Ethiopian there is a lack of appropriate blended fertilizer and lack of micronutrients in fertilizer blends are the major constraints to crop productivity [9].

Moreover, potassium has a crucial role in the higher productivity of potato tubers because it plays an important role in photosynthesis, regulation of opening and closing of stomata, favoring high energy status which helps in timely and appropriate nutrients translocation and water uptake in plants [10].

Assosa areas are deficient in macronutrients and micronutrients fertilizers [6]. For many years most researchers described that no potassium nutrient deficiency in Ethiopia. But recently the potassium nutrient deficiency was occurred in most part of our country like Assosa area. So, applying blended macronutrients and micronutrients fertilizers were improved potato yield and tuber size distribution at Assosa areas. Thus, this study was conducted with the objectives to select best performed potato varieties response to different rates of blended NPSZnB with potassium fertilizers and to determine optimum rate of the NPSZnB and potassium fertilizers for profitable production of potato at Assosa area.

2. Materials and Methods

2.1. Description of the Study Site

The trial was conducted at Asossa Agricultural Research Center in 2020 cropping season on June under rain fed condition, in Benishangul Gumuz Regional State of Ethiopia. The trial site is located at an elevation of about 1553 meters above sea level. Benishangul Gumuz Regional State is geographically located between 9 °30' to 11 °39" N latitude and 34 °20' to 36 °30"E longitude covering a total land area of 50,000 square kilometer. The trial site is located between 10 ° 02' 05" N latitude and 34 °34' 09" E longitudes. The trial site is located East of Asossa town and West of Addis Ababa about 4 km and 660 km distance, respectively. The total annual average rainfall of Asossa is 1275 mm. The minimum and maximum temperatures are 14.33 ℃ and 28.43 ℃, respectively. The dominant soil type of Asossa area is Nitosols and Fluvisols with the soil pH ranges from 5.1 to 6.0 [11].

2.2. Materials Used

The improved potato varieties called 'Belete (CIP-393371.58) and Gudane were used as tested crops. NPSZnB blended fertilizer was commercially formulated and selected for Assosa area, based on Ethio SISmap [12]. Nitrogen and Phosphorus fertilizers were adjusted for the blended NPSZnB fertilizer because of nitrogen and phosphorus found in blended fertilizers were very low for potato production. Adjusted nitrogen and phosphorus fertilizers were used from Urea and TSP source, respectively. Blended fertilizer, potassium chloride, half urea and adjusted phosphorus fertilizers were applied at planting and half urea was applied after 45 days.

2.3. Treatments and Experimental Design

The experiment was laid out in RCBD with split plot arrangement and treatments replicated three times. Belete and Gudane potato varieties were located in the main plot whereas the unfertilized control, recommended NPK and four rates of NPSZnB blended fertilizer with potassium chloride rates located in subplots. Totally, the experiment had twelve treatments. Each plot had a gross area of 11.25 m^2 with 3m length and 3.75m width. Each plot contained five rows of potato plants. Each of rows contains 10 plants per row with spacing of 0.75m and 0.30 m between rows and plants, respectively. The spacing between plots and adjacent blocks were 0.5 m and 1.5 m, respectively.

Table 1. *The detail nutrient contents of the blended fertilizer.*

S.N	Fertilizer types	Rates of NPSZnB plus adjusted NPK	Nutrient contents of NPSZnB
1	Control (0)	Control (0)	0
2	100% NPK	100% NPK (110 N+90 P_2O_5+69K_2O)	
3	50 %NPSZnB	50 %NPSZnB+ 46.15 N+27.35 P_2O_5 + 34.5 K_2O	8.85 N+17.65 P_2O_5+2.85 S+0.13 B+1.1 Zn

S.N	Fertilizer types	Rates of NPSZnB plus adjusted NPK	Nutrient contents of NPSZnB
4	100% NPSZnB	100% NPSZnB +92.3 N+ 54.7 P_2O_5 + 69 K_2O	17.7 N + 35.3 P_2O_5 +7.6 S + 0.25 B -2.2 Zn
5	150% NPSZnB	150% NPSZnB + 138.45 N+82.05 P_2O_5 + 103.5 K_2O	26.55 N+52.95 P_2O_5+11.4 S+0.38 B+ 3.3 Zn
6	200% NPSZnB	200% NPSZnB + 184.6 N+ 109.6 P_2O_5 + 138 K_2O	35.4 N+70.6 P_2O_5+15.2 S+0.5 B+4.4 Zn

SN: Serial Number, NPSZnB; Blended N: Nitrogen, P: Phosphorus, S: Sulfur, Zn: Zinc, B: Boron

2.4. Soil and Plant Sampling

Soil Sampling and Analysis

Twelve random surface soil samples (0-30cm) were collected following diagonal sampling technique from the entire experimental field before planting and a composite was made. The composite sample was air dried ground and passed through 2mm sieve for analysis of selected physicochemical properties. For determinations of organic carbon and total N, 0.5 mm sieve was used. Determinations of the soil physico-chemical properties were carried out following standard laboratory procedures.

Composite soil samples (from 10 spots) were collected at 0-30cm depth with auger using diagonal sampling techniques from the whole field before planting. Thus, soil sample was subjected for physico-chemical analysis (soil texture, organic carbon, soil pH, total N, available P, exchangeable K and CEC). Bulk density was taken by using core sampler for analysis. The soil particle size distribution was determined using the hydrometer technique [13] while the soil textural class was identified from textural triangle [14]. The cation exchange capacity (CEC) was determined using 1*N*-neutral ammonium acetate method [15]. Soil pH was determined in 1: 2.5 soils to water ratio using a glass electrode attached to a digital pH meter [16].

Organic carbon content of the soil was determined following the wet oxidation method [17]. Total nitrogen was determined according to Kjeldahl procedure with sulfuric acid [18]. Exchangeable potassium was extracted using 1*N* neutral ammonium acetate methods at pH 7 [19] and determined with a flame photometer. Available phosphorus was determined by the Olsen method [20]. The available S in the soil samples was extracted with mono-calcium phosphate extract, while available Zn and B in the soil samples was extracted with diethyline triaminepenta acetic acid (DTPA) and quantified by atomic absorption spectrophotometer.

2.5. Collected Data

Field data were collected from the three middle rows, leaving aside plants in the border rows in order to avoid border effects. Collected data include total tuber yield, potato tuber size distribution, and tuber quality parameters.

Total tuber yield (t ha^{-1}): the sum of tuber yield weights of marketable and unmarketable tubers.

Tuber Quality Parameters

Specific gravity of tubers: was determined by the ratio of the tuber weight in air to the tubers weight in water method. Tubers of all shapes and size categories, which weighed about 3 kg, were randomly taken from each plot. The selected tuber was washed with water. The samples were first weighed in air and then re-weighed by suspended them in water. Specific gravity was calculated using the formula developed [21].

$$Specific\ Gravity = \frac{Weight\ in\ air\ (g)}{Weight\ in\ air(g) - Weight\ in\ Water(g)}$$

Tuber dry matter content (%): Five fresh tubers were randomly selected from each plot and weighed. The tubers were chopped and dried in an oven at 65 ℃ for 24 hours. The dry matter percent was calculated according to the following formula [22].

$$Tuber\ Dry\ matter\ Content = \frac{\text{Weight of sample after drying (g)}}{\text{Intial weight of sample (g)}} \text{ X } 100$$

Tuber size distribution in weight (g): refers to the proportional weight of tubers in size categories. All tubers from five randomly taken plants were categorized into small (less than 39 g); medium (39-75 g), and large (greater than 75 g) [4].

2.6. Statistical Analysis

Data were subjected to analysis of variance according to [23] version 9.0 and interpretations were made following the procedure [24]. The treatments having significant differences were separated by using LSD (Least Significant Difference) at 5% level of significance.

3. Results and Discussion

3.1. Selected Physicochemical Properties of the Experimental Soil Before Planting

The soil sample analysis results indicated that the soil was clay in texture with strongly acidic in reaction (pH 5.2). Several researchers were reported that at optimum growth of potato was found in the soil pH range of 5.2 to 6.5 [6, 25].

Table 1. *Selected physicochemical properties of the experimental soil before planting.*

Soil physicochemical properties	Contents	Rating	Reference
pH (H_2O)	5.2	strongly acidic	[26]
Sand (%)	24		
Silt (%)	22		
Clay (%)	54		
Textural Class	Clay		[27]
Organic carbon (%)	3.35	medium	[26, 28]
Organic matter (%)	5.8	medium	[26]
CEC (Cmol(+) kg^{-1}soil)	21.93	medium	[29]
Total nitrogen (%)	0.19	low	[26]
Exchangeable potassium (ppm)	9.98	very low	[26]
Available of phosphorus(mg/kg)	6.45	very low	[26]
Sulfur (ppm)	3.01	very low	[26]
Boron (ppm)	0.61	Low	[30]
Zinc (ppm)	0.34	very low	[26]

3.2. Potato Total Tuber Yield

The interaction effects of different potato varieties and blended NPSZnB with potassium chloride fertilizers rates were not significantly (P>0.05) affected the total tuber yield. The main effects of different rates of blended NPSZnB fertilizer with adjusted nitrogen, phosphorus and potassium chloride fertilizers were highly significant (P<0.01) in affecting the total tuber yield (Table 3). The highest total tuber yield (28.84 t ha^{-1}) was obtained by application of 200% NPSZnB with adjusted 184.6N+ 109.6 P_2O_5 + 138 K_2O whereas the lowest total tuber yield (10.17tha^{-1}) was recorded in unfertilized control. Application of blended NPSZnB and potassium chloride fertilizers rates from 50% to 200% with adjusted nitrogen, phosphorus increased total tuber yield relatively by about 48.06% to 60.21% over the unfertilized plot.

This result is in harmony with findings of [6] who reported that increasing the rates of 100% NPSZnB to 200%NPSZnB with adjusted nitrogen increased the total tuber yield by 10.33%. Generally, the this result indicated that application of blended NPSZnB with adjusted nitrogen, phosphorus and potassium chloride fertilizers increased tuber yields of potato similar to the findings of several researchers who stated positive response of potato in term of total tuber yields with increasing levels of blended NPS fertilizer rates at different agro-ecologies [31-33].

3.3. Tuber Quality Parameters

The analysis of variance indicated that the interaction effects of different potato varieties and different rates of blended NPSZnB with potassium chloride fertilizers were not significantly (P>0.05) affected tuber dry matter content and specific gravity (Table 3). The main effects of Belete and Gudane potato varieties were not significantly (P>0.05) influenced the tuber dry matter content and specific gravity (Table 2). Similarly, the effects of different rates of blended NPSZnB and potassium chloride fertilizers were not significantly (P>0.05) influenced specific gravity of potato (Table 3). This result is in line with several findings which stated that specific gravity of tubers was not significantly influenced due to N and P fertilizer application [34, 35, 6]. However, this result disagreement with other finding that specific gravity was significantly affected by the application of blended NPSB fertilizer [36].

The effects of different rates of blended NPSZnB and potassium chloride fertilizers were not significantly (P>0.05) affected tuber dry matter content of potato (Table 3). This result is disagreement with the finding that tuber dry matter content was significantly affected due to the application of chemical fertilizer rates and types [6].

3.4. Potato Tuber Size Distribution

The result is revealed that the interaction effects of different potato varieties and different rates of blended NPSZnB with potassium chloride fertilizers were not significantly ($P>0.05$) affected potato tuber size distribution (Table 3). The main effects of potato varieties were not significantly ($P>0.05$) influenced the potato tuber size distribution (Table 3).

3.4.1. Small Sized Potato Tuber (<39g)

The analysis of variance indicated that the interaction effects of different potato varieties and different rates of blended NPSZnB with potassium chloride fertilizers was not significantly ($P>0.05$) affected small sized potato tuber (Table 3). Application of different rates of blended NPSZnB and Potassium chloride fertilizers were significantly ($P<0.05$) affected small sized potato tuber (Table 3). The proportion of small-sized potato tubers significantly decreased by 67.32% to 37.39% with increasing rates of blended NPSZnB and potassium chloride with adjusted nitrogen and phosphorus fertilizers from 0 to 200% NPSZnB fertilizers, respectively. This result is line with the findings of [36] who stated that application of blended NPSB fertilizer was significantly influenced the small sized potato tuber.

3.4.2. Medium Sized Potato Tuber (39-75g)

The interaction effects of potato varieties and different rates of blended NPSZnB with potassium chloride fertilizers were not significantly ($P>0.05$) affected medium sized potato tuber. However, application of different rates of blended NPSZnB and potassium chloride with adjusted nitrogen, phosphorus fertilizers were highly significant ($P<0.01$) influenced medium size potato tuber (Table 2). This result is similar with the finding of [6] who reported that applying chemical fertilizer types and rates significantly affected the medium sized potato tuber.

Application of different rates of blended NPSZnB and potassium chloride with adjusted nitrogen, phosphorus fertilizers increased the percentage of medium sized potato tuber as compared to unfertilized plot. The proportion of medium-sized potato tubers were significantly decreased by 49.35% to 14.61% with increasing rates of blended 50% to 150 % NPSZnB and potassium chloride with adjusted nitrogen and phosphorus fertilizers, respectively. This might be due to additional adjustment of nitrogen and phosphorus to blended NPSZnB fertilizers. The adjustment of nitrogen and phosphorus fertilizers might be decreased the proportion of medium sized potato tuber by enhancing the proportion of large sized potato tuber. The result is disagreement with other researcher findings which increasing application of blended NPSB fertilizer from 0 to 250 kg significantly increased the percentage of medium tuber size by about 44% [36].

3.4.3. Large Sized Potato Tuber (>75g)

The interaction effects of potato varieties and blended NPSZnB fertilizer rates were not significantly affected large sized potato tuber (Table 3). Large sized potato tubers were highly significant ($P<0.01$) affected by application of different rates of blended NPSZnB and potassium chloride with adjusted nitrogen, phosphorus fertilizers (Table 3). The highest yield of large sized potato tubers were obtained 200% NPSZnB + 184.6N+ 109.6 P_2O_5 + 138 kg K_2O per ha.

Increasing application of blended NPSZnB fertilizer from 0 to 150% and potassium chloride with the adjusted nitrogen and phosphorus significantly increased the percentage of large tuber size by about 46.84% over unfertilized plot. This result is in consistency with the findings of [36] who reported that increasing application of NPSB fertilizer from 0 to 300 kg ha^{-1} increased the proportion of large tuber size linearly. Similarly, the result are in consistency with findings of [6] which reported significant response in large tuber size due to application of chemical fertilizer types and rates. Generally, the present result revealed that increasing the rate of blended NPSZnB and potassium chloride with adjusted nitrogen and phosphorus fertilizers application increased the proportion of large-size tubers. The result of the present finding agreement with authors, [37] who reported that increased in yield of tubers with increase in applied nitrogen was associated with increases in the number of tubers in the large categories at the expense of the small ones due to increase in the weight of individual tubers. In addition to that potassium application plays significant role in increasing yield of potato tubers which is either due to formation of large sized tubers or increasing number of tubers per plants or both by helping in accumulation of carbohydrate.

Table 3. Main effects of blended NPSZnB with potassium chloride fertilizers rates on potato quality traits and tuber size distribution at Assosa.

Varieties	TDMC (%)	SG	Potato tuber size distribution in %			
			SS (<39g)	MS (39-75g)	LS (>75g)	TTY (tha^{-1})
Belete	19.05	1.097	7.5	29.56	62.94	29.41
Gudane	20.43	1.092	12.24	40.42	47.34	26.27
LSD	Ns	Ns	Ns	Ns	Ns	Ns
Fertilizers						

Varieties	TDMC (%)	SG	Potato tuber size distribution in %			
			SS (<39g)	MS (39-75g)	LS (>75g)	TTY (tha^{-1})
Control	20.19	1.08	14.79ab	48.65a	36.55c	13.18c
100%NPK	21.47	1.09	15.13a	31.08cd	53.78b	30.94a
50%NPSZnB	17.95	1.097	9.26abc	41.54ab	49.2b	25.38b
100%NPSZnB	19.04	1.097	8.54bc	36.73bc	54.73b	30.86a
150%NPSZnB	22.49	1.103	6.62c	24.64d	68.75a	32.98a
200%NPSZnB	17.31	1.097	4.86c	27.29cd	67.84a	33.12a
LSD	Ns	Ns	13.18	10.31	9.85	8.93
CV	15.63	1.87	55.25	22.84	26.17	13.03

The same letter within a column are not significantly different at 5% level of significance; Ns = Not Significant; LSD = least significant difference; and CV= Coefficient of Variation; SG= Specific Gravity; TDMC = Tuber dry matter Content in percentage, SS= Small size, MS= Medium size, LS= Large Size, TTY= Total Tuber Yield

4. Conclusions

Increasing application of blended NPSZnB and potassium chloride fertilizers rates from 0 to 200 kg increased the yield of potato tuber relatively by about 48.07% to 60.21% over the unfertilized plot. The highest total tuber yield and large sized potato tuber yield parameters were obtained by application of 200% NPSZnB + 184.6kg N+ 109.6kg P_2O_5 + 138kg ha^{-1} K_2O. Improved Belete potato variety reflected higher yield than Gudane potato variety. In conclusion, application of 200% NPSZnB + 184.6N+ 109.6 P_2O_5 + 138 K_2O fertilizers induced the highest yield of Belete potato variety in comparison with Gudane potato variety. Based on present study results; application of 200% NPSZnB + 184.6N+ 109.6 P_2O_5 + 138kg K_2O ha^{-1} fertilizer is recommended for the production of Belete potato variety on soil with low content of macronutrients and micronutrients fertilizers under given local conditions of study site.

Abbreviations

RCBD	Randomized Complete Block Design
CIP	International Potato Center
pH	Potential of Hydrogen

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Author Contributions

Desta Bekele is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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