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ORIGINAL RESEARCH ARTICLE



Determining the rate of blended fertilizers and urea for potato production under rainfed condition in Jeldu, West Showa, Ethiopia

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ABSTRACT

This experiment was conducted to determine the rate of blended fertilizers and urea for potato production under rainfed condition in Jeldu, West Showa, Ethiopia. Different fertilizer treatments viz., 150 kg ha⁻¹ NPSB+80 kg ha⁻¹ urea, 250 kg ha⁻¹ NPSB+80 kg ha⁻¹ urea, 350 kg ha⁻¹ NPSB+80 kg ha⁻¹ urea, 150 kg ha⁻¹ NPSB+140 kg ha⁻¹ urea, 250 kg ha⁻¹ NPSB+140 kg ha⁻¹ urea, 350 kg ha⁻¹ NPSB+140 kg ha⁻¹ urea, 150 kg ha⁻¹ NPSB +200 kg ha⁻¹ urea, 250 kg ha⁻¹ NPSB +200 kg ha⁻¹ urea and 350 kg ha⁻¹ N+200 kg ha⁻¹ urea was used for the production of Belete and Gudenie potato varieties (cv. Jeldu Wereda) during 2018-2019 using RCBD factorial arrangement in three replication. This study revealed that there was a highly significant difference between the yield and yield components of potato due to the main effect of fertilizer rates. The interaction did not significantly affect any parameter of potato during the study. The highest total and marketable yields (22.95 t ha⁻¹ and 20.06 t ha⁻¹), respectively were harvested from 350 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea though not significantly different from total and marketable yield of 250 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea (22.08 and 19.14 t ha⁻¹) and 350 kg ha⁻¹ + 140 kg ha⁻¹ urea (21.65 and 18.84 t ha⁻¹), respectively. The partial budget analysis indicated that the highest benefit (64,916.00ETB) was fetched from 350 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea followed by 250 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea (63,004.00ETB) while the highest marginal rate of return (19,430.00%) was recorded from 250 kg ha⁻¹ NPSB+200 kg ha⁻¹ followed by 150 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea (17,000.00%). From this, it can be concluded that the NPSB+ urea rates highly significantly affected the yield and yield component of potato. Thus, 250 kg ha⁻¹ urea+200 kg ha⁻¹ urea can be used for high yield and high economic return of potato in Jeldu district.

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is a top vegetable crop in Ethiopia (Amin, 2013). It is regarded as a high potential food security crop for densely populated highland areas (Hirpa *et al.*, 2010) and the Ethiopian government has identified it as one of the priority crops for agricultural growth programmers (Tesfaye

et al., 2012). Potato is one of the most suiting crops to high land areas of Ethiopian, which can produce a higher yield per unit time and land. Its production was showed a remarkable increase from time to time and reached 572,000 tons to 3.66 million tons with the land coverage increment of 160,000-296,557.5 ha from 2001- 2015 (CSA, 2001, 2015/16). This increase implies the annual average productivity of 12.66 t/ha

which was 5.7 in 2001. The 12.66 t/ha average productivity is low when compared with the world (19 t ha⁻¹) and other African countries. This is due to a combination of genotypic and environmental factors which can be explained as varietal and poor agronomic activities applied and climatic influence. One of the poor agronomic practices is cultivation with low or no fertilizer use which is common practice in Ethiopian farmers (Gezu, 2015). As indicated in Chillot and Hassan (2010) lower levels of fertilizer use and/or inappropriate type of fertilizer application is one of the productivity problems. Human interventions are mentioned as the cause of soil nutrient depletion (Chillot and Hassan, 2010); which can significantly influence food security in the country (MoARD, 2010). Inappropriate soil fertility management is the cause of food shortage and malnutrition of tremendous peoples which have also an associated health impact (Gete et al., 2010). Ethiopian soils' S and B shortage are one of the yield-limiting factors (Assefa et al., 2020). Inappropriate cropping systems, mono-cropping, nutrient mining, unbalanced nutrient application, removal of crop residues from the fields and inadequate resupplies of nutrients have contributed to declines in crop yields (Nyamangara et al., 2001). Soil fertility Declining is an important bottleneck for smallholder crop growers in central and western parts of Ethiopia (Tolera et al., 2009). Continuous monocultures of cereals also result in the reduction of yields and soil nutrients (Zerihun et al., 2013 and Kombiok et al., 2008). According to Fassil and Charle (2009) soil degradation and nutrient depletion have gradually increasing and increasing; now become a serious problem to agricultural productivity in Ethiopia. Previously, fertilizer use and recommendation was limited to N and P; now, plant nutrients like K, S, and Zn as well as B and Cu are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country (ATA, 2016). Most Ethiopian soils are deficit in macronutrients (N, P, K, and S) and micronutrients (Cu, B, and Zn) (EthioSIS, 2014). As a result, the government has given attention to fertilizer types to be applied to crops and developed new blended fertilizer type recommendation for most Kebele's of districts of Oromia region despite the rates to be applied including all the deficient element based on soil test result. Conducting trial is a must to identify the amount of blended fertilizer to be applied. To solve this problem this experiment was conducted to determine and recommend the rates of blended fertilizers for potato growers of the Jeldu districts of Oromia region using Gudenie and Belete potato varieties.

Table 1. Soil analysis before planting for the growing location.

Replication	pH	P (ppm)	N (%)	OC (%)	CEC (meq/100g)	Ex Al ³⁺		Texture (%)		
						(Meq/100g)	Clay	Silt	Sand	
1	4.99	28.89	0.18	2.99	44.82	1.52	42.50	32.50	25.00	
2	5.00	22.97	0.30	3.80	39.76	1.41	30.00	42.50	27.50	
3	5.00	20.12	0.37	2.69	39.18	2.71	42.50	42.50	15.00	
Average	5.00	23.99	0.28	3.16	41.25	1.88	38.33	39.17	22.50	

P ppm=available phosphorus parts per million; N%= total nitrogen in percent; OC % = Organic carbon in percent; CEC (meq/100g) = cation exchange capacity (meq/100g); Ex Al³⁺(meq/100g) = exchangeable aluminum (meq/100g).

MATERIALS AND METHODS

Experimentation

This experiment was conducted on Belete and Gudenie potato varieties; and ten fertilizer treatments in Jeldu districts in 2018-2019 main cropping seasons (June-August) using completely randomized block design arrangement with three replications. The fertilizer treatments were Control, 150 kg ha⁻¹ NPSBr+80 kg ha⁻¹ urea, 250 kg ha⁻¹ NPSB+80 kg ha⁻¹ urea, 350 kg ha⁻¹ NPSB+80 kg ha⁻¹ urea, 150 kg ha⁻¹ NPSB+140 kg ha⁻¹ urea, 250 kg ha⁻¹ NPSB+140 kg ha⁻¹ urea, 350 kg ha⁻¹ NPSB+140 kg ha⁻¹ urea, 150 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea, 250 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea and 350 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea. The blended fertilizers types were NPSB (N=18.9%, P=37.7%, S=6.95%, B=0.1% content) and urea. The soil sample was taken from 0-30cm depth for analysis and the result was found in Table 1.

The land was prepared well by plowing 3-4 times until fine tilth was achieved in similar ways of land preparation rule for potato fields in the Holleta research center. Tubers used for planting was a similar size for the varieties. The sprouted tubers were planted in 10 cm depth with a 75cm distance between rows and 30cm between plants on 4.5m × 3m plot size. The distance between block was 1.0m and the plot was 0.5m. All Blended NPSB fertilizer treatments and half amount urea were applied during planting while the remaining half of urea applied during the start of flowering. All cultural practices except fertilizer treatment were done in the same practice as Holleta research center recommended practice for potato production. Tuber harvesting was done once at proper physiological maturity (70% leaves withering). A tuber dry matter was measured after drying sample biomass in oven dry at 75°C until constant weight achievement.

Data collection

During harvesting, tubers were categorized into marketable and un-marketable yields. Marketable tubers were tubers that were greater than 20mm in diameter and free of cracking, diseases, insect and mechanical damage. The tuber dry matter was prepared from 300gm sample tubers by drying it in an oven at 75°C temperature until the constant dry weight was achieved. The data collected were total and marketable tuber number per plot, total tuber and marketable yields in ton/ha, average tuber number/plant and weight/ tuber, tuber dry weight in %, plant height and main stem number.

Data analysis

Data were subjected to analysis of variance using proc GLM (general linear model) procedure of SAS 9.2 software (SAS Institute Inc. 2009). The means were compared with the Least Significant Difference (LSD) at 5% significance level and the partial budget analysis was conducted.

RESULTS AND DISCUSSION

Soil analysis result before planting

Soil pH: The average pH value before planting was generally 5.00 (Table 1) which is highly acidic soil reaction (Herrera, 2005) with PH values ranging less than 5.5. This pH rage is not good for nutrient uptake by the plants (Warren, 2004). The pH value reported for the experimental soil does have the toxicity of aluminum, manganese, and hydrogen; rather than an abundance of cations like K^{+1} , Ca^{+2} , and Mg^{+2} (Fall, 1998). EthioSIS (2013) classify soil pH values less 4.5 strongly acidic, between 4.5 and 5.5 highly acidic, between 5.6 and 6.5 moderately acidic, between 6.6 and 7.3 neutral, between 7.4 and 8.4 moderately alkaline, and greater than 8.5 strongly alkaline. The pH of the soil between 5.00 and 7.55 is found within a suitable range for crop Production (Sahlemdhin, 1999). According to FAO (2000) report the pH range of most crops was 4-8 because of variable optimum pH requirement of different crops. Optimal soil pH for potato is indicated as 5 to 5.5 (McCauley et al., 2017). Thus, the pH of the experimental soil is almost within the range for productive soils of potato crop, though it has negative impact on nutrient availability.

Available phosphorus: The available phosphorus content of the growing location soil was 28.89 ppm, 22.97ppm, 20.12 for replications I, II, and III, respectively (Table 1) and the average was

23.99ppm which were all in general in the medium range of available phosphorus according to Tekalign (1991) rating as he rated $P < 10$ ppm low, 11-31ppm medium, 32-56 high and very high when $P > 56$ ppm. Bray and Kurz (1945) soil phosphorus range rating also confirms the result as it was in medium because they indicated < 7 , 8-19, 20-39, 40-58 and > 59 was very low, low, medium, high and very high, respectively.

Total soil nitrogen: The average soil total nitrogen of the site before planting was 0.28% (Table 1) which is in the high range according to the rating of Havlin et al. (1999) as total nitrogen level below 0.1% very low, 0.1 to 0.15 % low, 0.15 to 0.25 % medium, and high > 0.25 %. But, according to EthioSIS (2014) total nitrogen content rating (< 0.1 , 0.1-0.15, 0.15-0.3, 0.3-0.5, and > 0.5 was very low, low, medium, high and very high, respectively), it is in the medium range.

Organic carbon: The average organic carbon of the soil of the growing location was 3.16 % (Table 1) which was very high according to Tekalign (1991) rating. Soil organic carbon percentages of < 0.60 , 0.6- 1.0, 1.0 - 1.80, 1.80 -3.0, and > 3 as very low, low, medium, high and very high, respectively (EthioSIS, 2013).

Cation exchange capacity: The cation exchange capacity of the experimental area before planting was 41.25 (Table 1) which is a very high cation exchange capacity value according to Murphy (2007) rating, as he mentioned CEC content of the soil was very low when less than 6, low when between 6 and 12, medium when between 12 and 25, high when between 25 and 40; and very high when greater than 40. In line with this Landon (1991) report also in conformity with the result as he also rated CEC of > 40 , 25-40, 15-25, 5-15, < 5 $cmol\ kg^{-1}$ as very high, high, medium, low and very low, respectively.

Table 2. Effect of NPSB and Urea fertilizers on potato dry matter, height, and stem number, yield, and yield components.

NPSB+ Urea kg/ha	pH(cm)	SN	DM %	ATN/ plant	ATW/ tuber(g)	MTN/ plot	TTN/ plot
350+200	42.09a	3.33	21.38d	8.73ab	59.41a	189a	242a
350+140	40.39ab	3.22	21.22d	8.83a	56.25ab	186a	244a
250+200	39.28abc	3.24	22.55ab	8.81a	56.89ab	186a	241a
350+80	36.56c	3.09	22.31bc	8.44abc	53.71bc	177ab	233ab
250+140	40.16ab	2.92	21.78cd	8.23abcd	56.96ab	180ab	232ab
250+80	39.66ab	3.26	22.33bc	8.14bcd	50.11cd	156c	211cd
150+200	37.84bc	3.27	22.20bc	8.03cd	58.09ab	172b	221bc
150+140	40.66ab	3.2	21.87bcd	8.01cd	50.62cd	153c	211cd
150+80	38.23bc	3.23	22.12bc	7.67d	48.19d	149c	204d
Control	31.17d	2.87	23.17a	5.22e	47.15d	89d	129e
LSD	2.8928		0.6923	0.66	4.44	14.00	17.00
CV	16.14	26.72	6.75	17.80	17.80	18.7	16.90
P-value	<.0001	NS	<.0001	<.0001	<.0001	<.0001	<.0001

PH (cm) =plant height in cm, SN=stem number, DM %= tuber dry matter in percent, ATN/plant= Average tuber number per plant, ATW /tuber (g)= Average tuber number per tuber in g, TTN/plot= Total tuber number per plot, MTN/plot=Marketable tuber number per plot.

Soil particle distribution: The soil particle size percentage of the soil of production land was 38.33% for clay, 39.17% for slit and 22.50% for sand (Table 1) that would have been given clay loam soil (Table 1). The soil textural class of the experimental site was not far from the ideal soil textural class requirement of potato as it is sandy loam.

From these, it is concluded that, rather than nutrient availability, the aluminum toxicity is the yield reducing factor in Jeldu potato growing areas as it was 1.88 emq/100g (Table 1), though the amount of fertilizer applied to satisfy the crop needs, disease control and other cultural practices also have their own contribution to the reduction of the yield. According to Ajoy et al. (1988) aluminum is toxic to plant after pH value of less than 5.5. It inhibits root elongation and expansion as well as up take, transport and use of most important nutrients like K, P, Ca, Mg, Cu, Zn, and Fe which have great role in growth, development and productivity of the crop (Ajoy et al., 1988).

Plant height: There was a highly significant difference among plant heights due to the impact of fertilizer treatments applied and variety (Tables 2 and 3). The interactions did not significantly affect plant height. The highest plant height (42.09cm) was recorded at a fertilizer application rate of 350 kg ha⁻¹ NPSB + 200 kg ha⁻¹ urea even though not significantly different from 150 kg ha⁻¹ NPSB + 140 kg ha⁻¹ urea, 350 kg ha⁻¹ NPSB + 140 kg ha⁻¹ urea as well as 250 kg ha⁻¹ NPSB + 140 kg ha⁻¹ urea while the lowest plant height was registered from control (Table 2). Significantly higher plant height (39.53cm) was obtained from Belete while Gudenie provided lower plant height (37.67cm) (Table 3). The growing year did not significantly affect plant height (Table 3). Increasing fertilizer rates increased plant height. This is probably due to the crop nutrient need satisfaction and growing condition favorability that make the crop to take up the applied nutrient and use it for more plant height growth due to applied Boron as it assists the root to absorb

more nutrient (Rut-Duga et al., 2019). This result was in agreement with Melkamu et al. (2019), who reported the highest plant height at the highest fertilizer applied. It is also in conformity with Mulugeta et al. (2019). Significantly higher plant height (39.53cm) was obtained from Belete while Gudenie provided lower plant height (37.67cm). This is due to the genetic potential difference between the two varieties.

Stem number: The main stem number was not significantly affected by fertilizer rates (Table 2). Both growing year and variety affected the main stem number highly significantly (Table 3). The higher 3.48 and 3.34 main stem numbers were observed from the 2019 growing year and Gudenie variety, respectively (Table 3). Interactions did not significantly influence the main stem number. These results conform with reports of some researchers in that stem number is not influenced by mineral fertilizers but affected by physiological age of the seed tuber (Asiedu et al., 2003), storage condition of tubers, number of viable sprouts at planting, sprout damage at the time of planting and growing conditions (Firman and Allen, 2007), variety and tuber size (Park et al., 2009).

Dry matter: The tuber dry matter in percent was highly significant in being affected by fertilizer rates (Table 2). The interactions did not significantly affect tuber dry matter. Increasing fertilizer rates decreased the potato tuber dry matter. The highest dry matter (23.17%) was observed at control treatment followed by the dry matter (22.55%) of 250 kg ha⁻¹ NPSB + 200 kg ha⁻¹ urea; and not significantly different lowest dry matter were observed at 350 kg ha⁻¹ NPSB + 200 kg ha⁻¹ urea (21.38%) and 350 kg ha⁻¹ NPSB + 140 kg ha⁻¹ urea (21.22%) (Table 2). Variety and growing year were highly significant in affecting tuber dry matter (Table 3). The higher 24.03% and 22.54 % tuber dry matter were produced during the 2018 growing year and Belete variety, respectively.

Table 3. Effect of year and variety on potato dry matter, height, stems number, yield, and yield component.

Year	PH(cm)	SN	DM (%)	ATN/ plant	ATW/ tuber	MTN/ plot	TTN/ plot	TTY t/ha	MTY t/ha
2018	38.1	2.85b	24.03a	7.09b	57.95a	145.82b	196.63b	18.36b	16.00
2019	39.12	3.48a	20.16b	8.94a	49.53b	181.43a	236.98a	19.73a	16.82
LSD		0.18	0.31	0.30	1.99	6.36	7.61	0.86	
P-value	NS	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.002	NS
Variety									
Belete	39.53a	2.98b	22.54a	7.95	61.94a	165.43	215.08	21.55a	18.72a
Gudenie	37.67b	3.34a	21.64b	8.07	45.54b	161.82	218.53	16.54	14.10b
LSD	1.29	0.18	0.31		1.99			0.86	0.84
P-value	0.005	<.0001	<.0001	NS	<.0001	NS	NS	<.0001	<.0001
CV	16.14	26.72	6.75	17.80	17.80	18.70	16.90	21.74	24.56

PH (cm)=plant height in cm, SN=stem number, DM %= tuber dry matter in percent, ATN/plant= Average tuber number per plant, ATW/tuber(g)= Average tuber number per tuber in g, TTN/plot= Total tuber number per plot, MTN/plot=Marketable tuber number per plot, TTY t/ha= Total tuber yield ton per hectare, MTY t/ha= marketable tuber number ton per hectare.

Average tuber number and weight: The average tuber number per plant and weight per tuber were highly significantly affected by the fertilizer rates (Table 2). The highest average tuber number was recorded from 350 kg ha⁻¹ NPSB + 140 kg ha⁻¹ urea followed by 250 kg ha⁻¹ NPSB + 200 kg ha⁻¹ urea and 350 kg ha⁻¹ NPSB + 200 kg ha⁻¹ urea while the lowest was recorded at control (Table 2). The maximum average tuber weight per tuber was provided by 350 kg ha⁻¹ NPSB + 200 kg ha⁻¹ urea followed by 150 kg ha⁻¹ NPSB + 200 kg ha⁻¹ urea, 250 kg ha⁻¹ NPSB + 140 kg ha⁻¹ urea as well as 250 kg ha⁻¹ NPSB + 200 kg ha⁻¹ urea while the lowest was recorded from control (Table 2). The growing year highly significantly affected both average tuber number and weight (Table 3). The higher average tuber number (8.94) was registered from 2019 while the higher average tuber weight (57.95) was recorded from 2018. The variety was highly significant in affecting average tuber weight (Table 3). Belete variety produced higher average tuber weight (61.94 g). The current result is consistent with Israel *et al.* (2012) who reported an increase in total tuber yield and average tuber weight with increased nitrogen and phosphorous fertilizer application. Similarly, Singh *et al.* (2016) reported that the application of 180 kg/ha nitrogen with 50 kg/ha sulfur, increased the number of tubers by 43%. The application of phosphorus fertilizer had a significant contribution to the increase in total tuber yield and the total number of tubers per plant as compared to unfertilized (Rosen and Bierman, 2008).

Total and marketable tuber number: The fertilizer treatments were highly significant in affecting the total and marketable tuber numbers (Table 2) while the variety was not significant in affecting total and marketable tuber numbers (Table 3). The highest total and marketable tuber number were produced by 350 kg ha⁻¹ NPSB and 200 kg ha⁻¹ urea followed by 350 kg ha⁻¹ NPSB and 140 kg ha⁻¹ urea, and 250 kg ha⁻¹ NPSB and 200 kg ha⁻¹ urea while the lowest was recorded at control (Table 2). The growing year had highly significantly affected total and marketable tuber number (Table 3). The higher 236.98 and 181.43 total and marketable tuber numbers were observed during the 2019 growing season, respectively. These results are in agreement with Singh *et al.* (2016) who reported 43% increment of number of tubers due to the application of 180 kg/ha nitrogen with 50 kg ha⁻¹ sulfur. The application of phosphorus fertilizer had a significant contribution to the increase in total tuber yield and the total number of tubers per plant as compared to unfertilized (Rosen and Bierman, 2008). The current result is consistent with Israel *et al.* (2012) who reported an increase in total tuber yield and average tuber weight with increased nitrogen and phosphorous fertilizer application.

Total and marketable tuber yield t ha⁻¹: The fertilizer treatments were highly significantly affected the total and marketable tuber yield (Figure 1). The highest total and marketable yield (22.95 t ha⁻¹ and 20.06 t ha⁻¹) were harvested from 350 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea though not significantly different from

total and marketable yield of 250 kg ha⁻¹ NPSB+200 kg ha⁻¹ (22.08 and 19.14 t ha⁻¹) and 350 kg ha⁻¹ + 140 kg ha⁻¹ urea (21.65 and 18.84 t ha⁻¹), respectively (Figure 1). The growing year was highly significant in affecting the total tuber yield but not significantly affected marketable tuber yield (Table 3). The higher the total tuber yield (19.73 t/ha) was produced during the 2019 growing year. Total and marketable tuber yield was highly significantly affected by variety (Table 3). The higher 21.55 t ha⁻¹ and 18.72 t ha⁻¹ total and marketable tuber yield respectively were provided by Belete variety. Increasing NPSB blended fertilizer from 0-150 kg ha⁻¹ resulted in a marketable yield increase of 82.32% while the further increase from 150-250 kg ha⁻¹ and 250-350 kg ha⁻¹ increases 25.59% and 10.68%, respectively. In other words, increasing 0-150, 0-250 and 0-350 kg ha⁻¹ resulted in marketable yield increment of 82.32%, 107.90%, and 118.58%, respectively. On the other hand, increasing urea fertilizer from 0-80 kg ha⁻¹ resulted in a marketable yield increase of 82.55% while the further increase from 80-140 kg ha⁻¹ and 140-200 kg ha⁻¹ increases 20.81% and 19.52%, respectively. In other words, increasing 0-80, 0-140 and 0-200 kg ha⁻¹ resulted in marketable yield increment of 82.55%, 103.36%, and 122.89%, respectively. According to Bewket *et al.* (2018), increasing the rates of sulfur resulted in to significant total tuber and marketable yield increased probably because of sulfur effect on the synthesis of sulfur containing amino acids, proteins, energy transformation, and activation of enzymes. Boron application also significantly increased tuber yield probably due to its role in regulation of carbohydrate metabolism and its transport within the plant besides the synthesis of amino acids and proteins (Walter and Rao, 2015). These results are in agreement with those of Singh *et al.* (2016) that reported the application of nitrogen, phosphorus and sulfur fertilizer resulted in a significant increment on marketable and total tuber yield. This could be probably since tuber number and size increase at higher nitrogen rate because nitrogen can promote the vegetative growth for more photo-assimilate production while phosphorous improved the development of roots for nutrient uptake and stolen for more tuber production. Israel *et al.* (2012) indicated that an increase in nitrogen and phosphorus application from 0 -165 kg ha⁻¹ and 0 - 60 kg ha⁻¹ were resulted in marketable tuber number increase by 56.36 and 19.2% respectively compared to control. Similarly, Singh *et al.* (2016) reported that the application of 180 kg/ha nitrogen with 50 kg/ha sulfur, increased the number of tubers by 43%. The application of phosphorus fertilizer had a significant contribution to the increase in total tuber yield and the total number of tubers per plant as compared to unfertilized (Rosen and Bierman, 2008). The current result is consistent with Israel *et al.* (2012) who reported an increase in total tuber yield and average tuber weight with increased nitrogen and phosphorous fertilizer application. Sulfur fertilizer application is reported for a significant increase in potato tuber yield by enlarging tuber sizes (Barczak *et al.*, 2013). According to the report of Mahmoodabad *et al.* (2010) and Sharma and Arora (1987), the increment of nitrogen fertilizer rate resulted in more tuber yield but the

excessive rate of nitrogen (250 kg ha^{-1}) decreased the total number of tubers per unit area and yield. Similarly, Sharma *et al.* (2011) reported that the application of sulfur fertilizer resulted in to significant differences in yield and raising the level 0 to 45 kg ha^{-1} increased total tuber yield per plant by 32.55%. In line with this, supporting report on the response of potato with the application of nitrogen and phosphorous fertilizers was mentioned in (Zelalem *et al.*, 2009).

Partial budget analysis: The highest benefit (64,916.00ETB) was gained from 350 kg ha^{-1} NPSB + 200 kg ha^{-1} urea followed by 250 kg ha^{-1} NPSB + 200 kg ha^{-1} urea (63,004.00 ETB) while the lowest benefit was obtained from control (Table 4). The highest marginal rate of return (19,430.00%) was provided by 250 kg ha^{-1} NPSB + 200 kg ha^{-1} urea followed by the marginal rate of return (17,000) generated at 150 kg ha^{-1} NPSB + 200 kg ha^{-1} urea (Table 4).

Table 4. Partial budget analysis.

Fertilizer rates kg ha^{-1} NPSB+Urea	variable cost ETB	Marginal cost ETB	Gross benefit ETB	Net benefit ETB	Marginal benefit ETB	Marginal rate of return %
Control	0.00		30,672.00	30,672.00		
150+80	3,060.00	3,060.00	49,752.00	46,692.00	16,020.00	523.53
150+140	3,780.00	720.00	54,036.00	50,256.00	35,640.00	495.00
250+80	4,460.00	680.00	57,132.00	52,672.00	2,416.00	355.29
150+200	4,500.00	40.00	63,972.00	59,472.00	6,800.00	17,000.00
250+140	5,180.00	680.00	65,268.00	60,088.00	616.00	90.59
350+80	5,860.00	680.00	61,092.00	55,232.00		
250+200	5,900.00	40.00	68,904.00	63,004.00	7,772.00	19,430.00
350+140	6,580.00	680.00	67,824.00	61,244.00		
350+200	7,300.00	720.00	72,216.00	64,916.00	3,672.00	510.00

Price for 100kg potato was 400ETB and yield adjustment factor 10%.

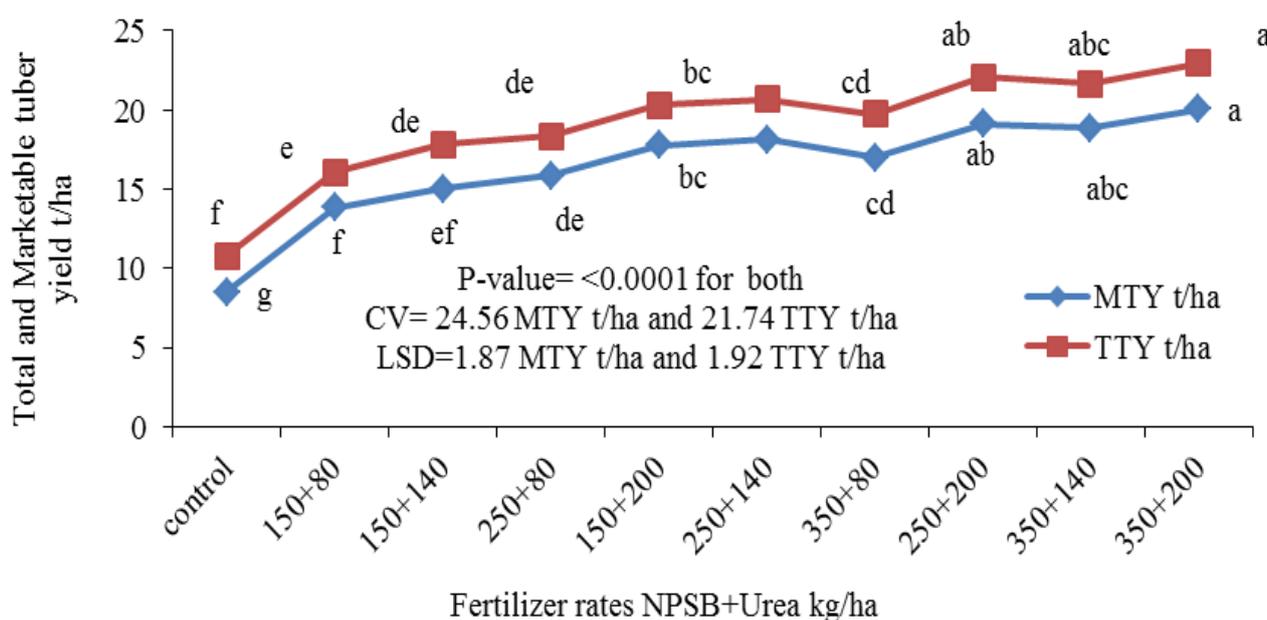


Figure 1. Effect of NPSB + Urea kg/ha on total and marketable tuber yield.

Conclusion

This study revealed that there was a significant difference between the yield and yield components due to fertilizer rates. The highest total and marketable yield (22.95 t ha⁻¹ and 20.06 t ha⁻¹) respectively were harvested from 350 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea though not significantly different from a total and marketable yield of 250 kg ha⁻¹ NPSB + 200 kg ha⁻¹ and 350 kg ha⁻¹ + 140 kg ha⁻¹ urea. The variety was also highly significant in affecting all parameters considered except average tuber number, total and marketable tuber number. The partial budget analysis indicated that the highest benefit (64,916.00ETB) was fetched from 350 kg ha⁻¹ +200 kg ha⁻¹ urea followed by 250 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea (63,004.00ETB) while the highest marginal rate of return (19,430.00) was recorded from 250 kg ha⁻¹ NPSB+200 kg ha⁻¹ urea followed by kg ha⁻¹ NPSB+200 kg ha⁻¹ urea (17,000.00). From this, it can be concluded that the fertilizer rates NPSB+ urea highly significantly affected the yield and yield component of potato. It is better to apply 250 kg ha⁻¹ urea+200 kg ha⁻¹ urea to the potato for high yield and high economic return in Jeldu district. In some cases where there is high P, it is also possible to apply 150 kg ha⁻¹ NPSB and 200 kg ha⁻¹ urea to potato to harvest reasonable yield with relatively small economic loss. It is better to repeat the experiment with more replication and higher rates including planting time as the farmer was planting starting from March. It is better if the future experiment will include application time.

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