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# Influence of blended fertilizer rates on the tuber yield of Irish Potato (Solanum tuberosum L.) on acid soils in Semen Ari District, Southwestern Ethiopia

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## ABSTRACT

*Soil fertility depletion is a serious problem in Ethiopian highlands due to leaching and erosion of topsoil by intense rainfall, which reduces potato production and productivity. The experiment was carried out for two consecutive years (including the years) with the objective of evaluating the influence of the blended NPSB fertilizer rates on the better production of Irish potato. The treatment consists of control (without fertilizers), 150kg NPSB + 91kg Urea, 200kg NPSB + 121kg Urea, 250kg NPSB + 152kg Urea and 300kg NPSB + 182kg Urea. To improve the at the soil acidity of the study site, 2 t ha-1 Calcitic lime (CaCO3) was broadcasted using hand and thoroughly mixed with the soil one month before planting the test crop. The treatments were arranged in randomized complete block design with three replications. Improved potato variety 'Belete' was used as a test crop and was planted early in the 'Belg' season. Composite soil sample was randomly collected before the application of lime in zigzag movement with the sampling depth of (0-20cm) and composited into one kg of a sample. The analysis results of the initial soil sample revealed that it was clay in texture, strongly acidic, medium in OC and available S, medium in available P, high in available K, and deficient in nitrogen and boron. The analysis of variance showed significant differences between the treatments on potato tuber yield and tuber number of tuber per plant. The maximum marketable yield (22874 kg ha-1), unmarketable yield (829 kg ha-1) and total tuber yield (23704 kg ha-1) were obtained from the application of 200 kg NPSB + 121 kg urea fertilizers. In terms of cost, the maximum net benefit of ETB 203,640.6 ha-1 with acceptable marginal rate of returns (MRR) of 5898.79% was obtained from 200 kg NPSB + 121 kg urea ha-1. Therefore, application of 200 kg NPSB + 121 kg urea ha-1 can be recommended for potato growers in the study area and other similar agro ecologies.*

## 1. INTRODUCTION

Potato is the most important horticultural crop, constituting the fourth most important food crop in the world after wheat, maize and rice and first among root and tuber crops followed by cassava, sweet potato, and yam (Douches 2013). Ethiopia has great potential for production of potato production, with 70% of the 13.5 million ha of arable land is suitable for potato cultivation (Vita 2015). The national average potato yield in Ethiopia is 13.9 t $ha^{-1}$ (CSA 2018), which is lower than the world average yield of up to 20 t $ha^{-1}$ (FAO 2019). Potato has shallow and inefficient rooting system (Munoz et al 2005) and crops absorbs maximum amount of nutrients from soil every season (Trehan et al 2005). Fertility status of soil, type, amount and time of fertilizer application has great influence on the yield and quality of potato production (Westermann 2005). Thus, the country is confronting with a great challenge: produce sufficient production for a fast-growing population on low fertility soils on land owned by poor smallholder farmers who are unlikely to afford maximum input use (Lulseged et al 2017).

Shiferaw and Anteneh (2014) reported that many surface soils in Ethiopia are already acidic in their natural state, current systems of agricultural land use systems aggravated the acidification. The increasing trend of soil acidity and exchangeable Al in arable and abandoned lands are attributed to intensive cultivation and continuous use of acid forming inorganic fertilizers. If it is not corrected, acidification can continue until irreparable damage takes place in the soil (Shiferaw and Anteneh 2014). Also, the current study showed that the status and magnitude of acidity in Ethiopia are 47% of the total area and 45% of the rain-fed areas are acidic ($pH < 6.5$). Of the total area of the Country, 3.7% (42,264 km2) is found to be extreme to strong acidic ($pH < 5.5$), 20.7% (236,724 km2) is moderate acidic ($5.6 < pH < 6.0$), and 22.5% (257,290 km2) is slight acidic ($6.0 < pH < 6.5$) (Gizaw et al 2021). Large areas of acidic soils occur in southern and southwestern regions of Ethiopia. Several adverse effects such as loss of crop diversity, decline in the yield of existing crops, lack of response to ammonium phosphate and urea fertilizers, and complete failure of crop yield due to soil acidity were reported (Wassie and Shiferaw 2009).

The average nutrient depletion in the highlands of Ethiopia, including the current research area, is much greater than in the lowlands (Henao and Baanante 1999). This is due to the reasons that the area receives maximum rainfall, creates high runoff and high soil erosion, fixation of phosphorus and leaching in respect of nitrogen and potassium. Soil fertility problem is the most important factor that limits the yield potentials of various crops including potato. In the study area, due to the acidity problem, the farmers abandoned to use their crop land for decades for all crops including potato. These might have led to the depletion of other important essential nutrients (Fanuel et al 2018) and consequently not satisfy the nutrient requirements of crops. Rutugna and Neel (2005) reported that crops responded to the combined application of lime and fertilizers in acid soils. Disappointing results from liming trials due to miss management of lime and not complimenting by appropriate fertilizer use to correct other critical factors were also reported (Shiferaw and Anteneh 2014). It is generally agreed that liming is essential to overcome soil acidity but should be combined with inorganic fertilizer to get adequate production. The soil fertility survey conducted in more than 150 districts in Ethiopia indicated that the soil lacks about seven nutrients: nitrogen (N), phosphorus (P), potassium (K), sulfur

(S), copper (Cu), zinc (Zn) and boron (B)) (EthioSIS 2014). To address all those problems, the Ministry of Ethiopian Agriculture introduced a new blended fertilizer NPSB (18.1% N, 36.1% P2O5, 6.7% S and 0.71%B) instead of DAP. However, crop and site-specific information regarding NPSB fertilizer for potato production is limited. Therefore, the study was conducted with the aim of evaluating the effect of rates of blended NPSB fertilizer on tuber yield and yield components of potato production.

## 2. MATERIALS AND METHODS

### 2.1. Description of the Study Area

A field experiment was conducted for two consecutive years (2018 and 2019) in Semen Ari district of South Omo Zone, Southwestern Ethiopia. The district is geographically located with the ranges of 6°08'- 6°27' N and 36°39'- 36°75' E with an elevation range of 900 to 3200 m.a.s.l. It is found in the northwestern direction with 85 km away from Jinka town (principal city of the southern Omo zone). The annual average rainfall in the district ranges between 601 to 1700 mm. The minimum and maximum annual temperatures of 10.71 to 11.50°C and 19.52 to 23.36°C, respectively. Rainfall of the district is bimodal, short rains start in February to April whereas; the second rain starts in July and ends in October with very big variations in distributions and amount (Source: Southern agro-meteorological observatory station). The study area has diversity of climate, soil, and landforms. The topography of the district includes mountains, hills, uplands and midland plains. The district generally experiences two cropping seasons namely belg and meher.

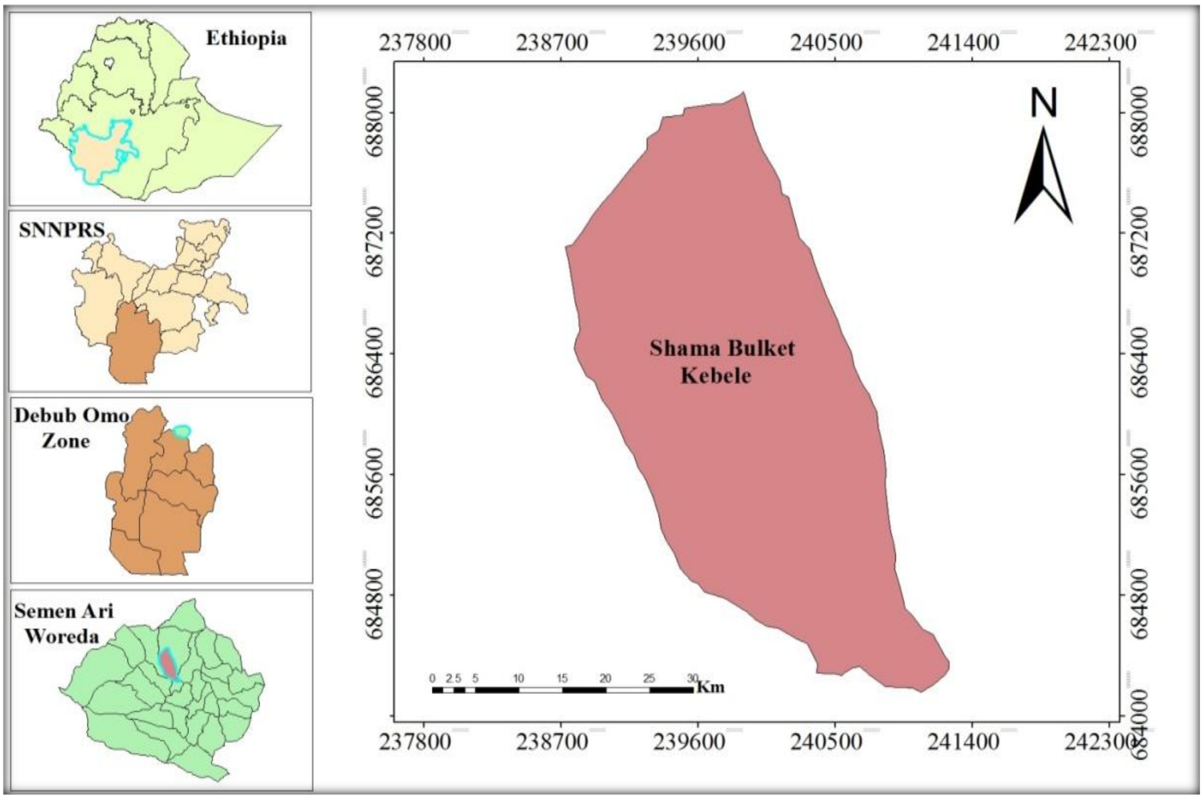


Figure 1. Map of study area

## Soil Sampling and Laboratory Procedures

Composite soil sample was randomly collected before the application of lime in zigzag movement with the sampling depth of (0-20cm) and composited into one kg of a sample. Following standard laboratory procedures, the soil samples were air dried and ground to pass in a 2 mm sieve for pH, available P, S, B and K, and in 0.5 mm sieve for OC and TN analysis. Particle size (soil texture) was determined by using the hydrometer method of Bouyoucos (Day 1965). The pH of the soils was measured in a water suspension in a 1:2.5 (soil: water ratio) and measured potentiometrically using a glass-calomel combination electrode (Van Reeuwijk 2002). The organic carbon content of the soil was determined following the wet combustion method of the Walkley and Black method as described by (Horneck et al 2011). The total nitrogen content of the soil was determined using the wet-oxidation (wet digestion) procedure of the Kjeldahl method (Horneck et al 2011). Available soil P was determined by the Bray method II using ammonium fluoride and hydrochloric acid as an extracting solution and it was measured by spectrophotometer (Bray and Kurtz 1945). The determination of extractable sulfur in soil extracts was made using the turbidimetric method. In this procedure, the sulfate is converted to a $BaSO_4$ suspension under controlled conditions. The result in turbidity is determined by a spectrophotometer and compared with a standard sulfate solution (Nagornyy 2013). Morgan's solution will be employed for extracting available $K^+$ and determined by a flame photometer (Morgan 1941). Soil micronutrient (B) was extracted with the diethylene triamine penta acetic acid (DTPA) method as described by (Lindsay and Norvell 1978). The concentration of boron in the extract was determined by an atomic absorption spectrophotometer.

## Experimental Design and Treatments

The experiment was carried out to evaluate the influence of the blended NPSB fertilizer rate on potato tuber yield by using randomized complete block design with three replications. There were five treatments, and the treatments were prepared based on the recommendations of the soil fertility map of Ethiopia produced by Agricultural Transformation Agency (ATA 2016). T1: Control (no fertilizers), T2: 150kg NPSB + 91kg urea, T3: 200kg NPSB + 121kg urea, T4: 250kg NPSB + 152kg urea and T5: 300kg NPSB + 182kg urea. To ameliorate the acidity of the study site, 2 t $ha^{-1}$ Calcitic lime ($CaCO_3$) was hand broadcasted and thoroughly mixed with the soils one month before planting of the test crop. All doses of NPSB were applied at planting after one month of lime application, while nitrogen was divided into two: half was applied at planting and the remaining half was applied 35 days after planting. The test crop used for this study was potato 'belete' variety collected from the Holeta Agricultural Research Center. The variety was chosen based on the results of adaptation and evaluation trial conducted on the study area. The spacing used was 1m between plots and replication with a plot size of 3.9m*3.75m.

## Experimental Procedure and Crop Management

Land preparation was carried out with oxen, and the soil was cleared of all unwanted materials and plant residues. Leveling was done manually using a hand hoe and the field layout was prepared. Medium-sized and well-sprouted potato tubers were planted on ridges at the specified spacing. The tubers were planted at a spacing of 0.75 m between the rows and 0.3 m between seed tubers placing one tuber per hill. The NPSB fertilizer at the specified rates was applied by banding a granule at the depth of 5 cm below at the seed tuber at planting. All necessary agronomic managements were carried out properly and uniformly for each plot from the field preparation to harvesting.

### Data Collection

The growth and yield related parameters were collected from selected harvestable areas to avoid border effects using standard procedures. Numbers of tubers per hill was recorded by counting the tubers of five randomly selected hills from harvestable rows at harvesting and the mean value was computed and used for further analysis. Tuber yields were free of mechanical, disease and insect pest damages and medium to large in size were considered as marketable. On the other hand, tubers that were damaged, small in size were considered unmarketable as described by (Tesfaye et al 2013). The weights of these tubers obtained from the harvestable area of each plot were measured in kilograms using a scaled balance and expressed in kg $ha^{-1}$ and considered as marketable yield as well as unmarketable tuber yield. Finally, the total tuber yield was obtained from the sum of marketable and unmarketable yields. Data were checked for homogeneity and normality and two-year combined data were subjected to analysis of variance.

### Data Analysis

The data collected from the experimental field for each variable were analyzed by the analysis of variance (ANOVA) procedure using the SAS statistical software (SAS 2007). Significant difference among treatment means was evaluated using the least significant difference (LSD) at $p < 0.05$.

### Economic Analysis

The economic evaluation comprises a partial budget analysis with dominance and marginal analysis. To estimate the economic parameters, the total yield was valued on average market price collected from the local markets during two consecutive years of production. The average yield was adjusted downward by 10% to reflect the difference between the experimental field and the expected yield at farmers' fields and with farmer's practices from the same treatments (CIMMYT 1988). The average cost of urea, NPSB and the average selling price of potato were 14.79, 15.48 and 10 Birr $kg^{-1}$ respectively. A wage rate of 50 birr per man per day was considered for fertilizer application. The dominance analysis procedure, which was used to select potentially profitable treatments, is carried out by first listing the treatments in order to increase the costs. Any treatment that has net benefits less than or equal to those of a treatment with lower costs that vary is dominated. For each pair of ranked undominated treatments, a percentage marginal rate of return (% MRR) was calculated as the ratio of differences between net benefits of successive treatments to the difference between total variable costs of successive treatments. (CIMMYT 1988). For a treatment to be considered a worthwhile option to farmers, the marginal rate of return (MRR) was calculated, and the minimum acceptable rate of return was considered to be 100%. Some of the concepts used in the partial budget analysis are gross field benefit (GFB), total variable cost (TVC), and net benefit (NB) were calculated.

## 3. RESULTS AND DISCUSSION

### 3.1. Soil Fertility Status of the Study Site before Planting

The soil fertility status of the study site before the application of lime and planting indicated that the textural class of the surface soil (0-20 cm) was clay, and the soil was strongly acidic (pH 5.15) with medium organic carbon (OC) and low total nitrogen (TN) contents (Tekalign 1991) and it is indicative of soil has probable yield responses to N application (Table 1).

Available phosphorus and potassium content were medium (Jones 2003) and available B content of the soil in the experimental field was low (Jones 2003). According to Hariram and Dwivedi (1994) the available sulfur content of the soil in the experimental field is a 16.96 ppm, which is medium for crop production.

Table 1: Some physical and chemical properties of the soil of the experimental site before planting

| Soil properties | Values | Rates | References |
|---|---|---|---|
| Clay | 50 | | |
| Silt | 24 | | |
| Sand | 26 | | |
| Textural class | | Clay | |
| pH($H_2O$) | 5.15 | Strongly acid | Tekalign 1991 |
| Organic carbon (%) | 1.8 | Medium | Tekalign 1991 |
| Total N (%) | 0.1 | Low | Tekalign 1991 |
| Available P (ppm) | 33.3 | Medium | Jones 2003 |
| Available S(ppm) | 16.96 | Medium | Hariram and Dwivedi 1994 |
| Available B (ppm) | 0.32 | Low | Jones 2003 |
| Available K (ppm) | 436.42 | Very high | Jones 2003 |

Generally, the soil fertility status of the experimental field was characterized to be low in total nitrogen and available B, and medium in available P and S, which might indicate the potential trait for reduced potato yield production. Therefore, the additional application of those nutrients could improve the tuber yield of potato in the study area.

### 3.2. Effects of NPSB Fertilizers on Tuber Yield and Yield Components of Irish Potato

The analysis of variance showed the effect of blended NPSB fertilizer rates on the tuber yield and yield components of Irish potatoes is shown in Table 2. The results indicated that the application of different rates of NPSB fertilizer significantly ($p<0.05$) affected the tuber yield and yield components including number of tubers per hill, the marketable yield, unmarketable yield and the total tuber yield of potatoes. The maximum number of tubers per hill was obtained from treatment with 250 kg NPSB + 152 kg of urea (13) and 200 kg of NPSB + 121 kg urea (12.7) and the minimum (5.7) was recorded from the control treatment. This result is in line with the other studies which noted that the maximum (16.00) total tuber number per hill was obtained from 200 kg NPSB whereas the minimum (7.87) was recorded from the unfertilized plot (Gezahegn et al 2021). However, increasing the NPSB supply beyond the 200 kg NPSB level did not significantly affect the total number of tubers per hill produced by the potato crop (Gezahegn et al 2021). The results also revealed that the maximum marketable yield (22874 kg ha$^{-1}$), unmarketable yield (829 kg ha$^{-1}$) and the total tuber yield (23704 kg ha$^{-1}$) were obtained from the application of 200 kg NPSB + 121 kg urea fertilizers. However, the minimum tuber yield and yield components were recorded in the control or unfertilized plot. The application of 200 kg of NPSB + 121 kg urea ha$^{-1}$ improves tuber yield production by 133.9% compared with the control.

The increase in tuber yield across applied fertilizer rates could be attributed to the fact that the applied lime before application of the treatments to ameliorate the acidity enhanced availability of N, P, S, and micronutrient like B which is significantly increased the overall number of tubers per hill of the plants that contributed to higher tuber yield. The yield advantage relative to the control (unfertilized) treatment might be an indication for the depletion of the soil and its response to fertilizer application. Therefore, blended fertilizer application based on soil test-crop response is very crucial to increase soil fertility and crop yield (Melkamu 2020). Likewise, the application of nitrogen with addition of sulfur nutrient had positive or synergetic effect (Marschner 2002). This positive interaction could be important in enhancing potato yield. Furthermore, sulfur is important for the production of chlorophyll and the utilization of phosphorus and other essential nutrients (Marschner 2002). Our result is also in agreement with other studies who reported the highest significant marketable yield (27.22 t $ha^{-1}$) and total tuber yield (30.55 t $ha^{-1}$) obtained from 200 kg NPSB $ha^{-1}$ application, while the lowest marketable (14.67 t $ha^{-1}$) and total yield (18.43 t $ha^{-1}$) were obtained from unfertilized plots (Gezahegn et al 2021).

Table 2: Tuber yield and yield components of the Irish potato under NPSB Fertilizer rate

| No. | Treatments kg/ha | No. tuber/hill | M/kg/ha | UM/kg/ha | Total Yld /kg/ha |
|---|---|---|---|---|---|
| 1 | Control | 5.7c | 9719d | 415b | 10133d |
| 2 | 150 kg NPSB + 91 kg urea | 8.7bc | 14874c | 593ab | 15467c |
| 3 | 200 kg NPSB+ 121 kg urea | 12.7a | 22874a | 829a | 23704a |
| 4 | 250 kg NPSB + 152kg urea | 13a | 21274ab | 533b | 21807ab |
| 5 | 300kg NPSB + 182 kg urea | 11.7ab | 18844b | 593ab | 19437b |
| LSD (5%) | | 3.4 | 3206 | 252 | 3185 |
| CV (%) | | 17.3 | 9.7 | 22.6 | 9.3 |

NB: Mean values with different letters in the column are statistically different at $\alpha \leq 5\%$.
Note: M = marketable tuber yield/ha in kg, UM = unmarketable tuber yield/ha in kg, Yld = tuber yield / ha in kg

**Economic Analysis**

The result of the partial budget analysis showed that the maximum net benefit of ETB 203640.6 $ha^{-1}$ with an acceptable marginal rate of return (MRR) of 5898.79% was obtained from the application of 200 kg of NPSB + 121 kg of urea, while the lowest net benefit (9197 ETB $ha^{-1}$) was obtained from no application of NPSB fertilizer (Table 3 and 4). The results of the study indicated that blended NPSB fertilizers with 200 kg $ha^{-1}$ + 121 kg $ha^{-1}$ urea had provided a promotion benefit over the control. Similarly, Tilahun (2017) reported the maximum net benefit of 31,782 Birr $ha^{-1}$ with the marginal rate of return of 1818% was obtained from the applications of 100 kg $ha^{-1}$ NPS and 69 kg $ha^{-1}$ N which indicates the economic feasibility of the application of blended fertilizer.

Table 3: Partial budget analysis of the Irish potato under NPSB Fertilizer

| Treatments | Total Yld /kg/ha | 10% Yld adjusted | GM | TVC | NB |
|---|---|---|---|---|---|
| Control | 10133 | 9119.7 | 91197 | 0 | 91197 |
| 150 kg NPS+91 kg urea | 15467 | 13920.3 | 139203 | 8459.64 | 130743.4 |
| 200 kg NPS +121 kg urea | 23704 | 21333.6 | 213336 | 9695.44 | 203640.6 |
| 250 kg NPS + 152kg urea | 21807 | 19626.3 | 196263 | 10946.51 | 185316.5 |

| | | | | | |
|---|---|---|---|---|---|
| 300kg NPS+182 kg urea | 19437 | 17493.3 | 174933 | 12182.31 | 162750.7 |

Note: Yld = Tuber yield/ha in kg, GM: Gross Margin (ETB/ha), TVC: Total variable cost (ETB/ha), and NR: Net Benefit (ETB/ha)

Table 4: Dominance and Marginal analysis

| Treatments | TVC | NB | MRR% |
|---|---|---|---|
| Control | 0 | 91197 | 0 |
| 150 kg NPS + 91 kg urea | 8459.64 | 130743.4 | 467.47 |
| 200 kg NPS + 121 kg urea | 9695.44 | 203640.6 | 5898.79 |
| 250 kg NPS + 152kg urea | 10946.51 | 185316.5 | D |
| 300kg NPS + 182 kg urea | 12182.31 | 162750.7 | D |

Note: TVC = Total variable cost (ETB/ha), NR = Net Benefit (ETB/ha) and MRR = Marginal Rate of Return

## 4. CONCLUSION AND RECOMMENDATION

The current study showed that the blended NPSB fertilizer with a rate of 200 kg $ha^{-1}$ + 121 kg $ha^{-1}$ urea has potential advantages over the control of potato production in the study area. The application of blended NPSB fertilize rates showed significant differences for the main tuber yield and the potato yield components. The application of blended fertilizer at the maximum rate of 200 kg NPSB + 121 kg urea $ha^{-1}$ resulted in the highest tuber yield, the marketable and the unmarketable yield, and number of tubers per hill. The partial budget analysis also revealed that the maximum net benefit of ETB 203640.6 ha-1 with acceptable marginal rate of returns (MRR) of 5898.79% was obtained from the rate of 200 kg NPSB + 121 kg urea ha-1 fertilizer application. Based on these results, 200 kg of NPSB + 121 kg urea $ha^{-1}$ gave the maximum tuber yield of 23704 kg $ha^{-1}$, which was profitable for the farmers in the study area. Therefore, it can be concluded that 200 kg NPSB + 121 kg urea $ha^{-1}$ blended fertilizer rate can be recommended for potato growers in the study area and other similar agro ecologies. Additional work is needed to verify the results and demonstrate them in wider areas for further use including NP and N alone fertilizer treatments.

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