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Evaluation of Potato (*Solanum tuberosum* L.) Varieties to Blended NPSB Fertilizers to Quality Traits and Economic Feasibility at Degam, Central Highlands of Oromia Region

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Abstract: Potato (*Solanum tuberosum* L.) is an important food and export crop in central highlands of Oromia region. The limiting macro and micronutrients were identified for the production of crops in Boneya districts, but the rates of these nutrients for high potato yield are not yet determined. Therefore, this research was conducted to determine the effect of blended NPSB fertilizer rates on tuber quality related traits and to estimate economically feasible blended NPSB fertilizer rate for potato production at Boneya Kebele, central highlands of Oromia region. The experiment was conducted as factorial combination of seven levels of blended NPSB fertilizer (0, 50, 100, 150, 200, 250, 300 kg ha^{-1}) and three potato varieties (Belete, Gudane, and Jalane) in a Randomized Complete Block Design with three replications. The results revealed that, neither the two main factors (variety and blended NPSB fertilizer) nor their interaction influenced tuber quality related traits. The net benefit obtained from Gudane and Belete varieties was determined by about 72.06 (R^2=0.07206) and 81.92% (R^2=0.08192), respectively, with the application of NPSB fertilizer and the relationship was linear and significant. The highest MRR (marginal rate of return) of 1802.35% was also obtained from Gudane variety with the application of 50 kg ha^{-1} NPS fertilizer, however, the highest net benefit of 166175.5 followed by 158899 Birr ha^{-1} was obtained from Gudane and Belete varieties, respectively, with the application of highest NPSB fertilizer rate of 300 kg ha^{-1}. The combinations of Gudane and Belete varieties with the highest rate of fertilizer also had acceptable MRR of 1434.17 and 760.27%, respectively. Therefore, growing of the two varieties at highest rates of NPSB fertilizer could be recommend for producers because of the high economic returns.

Keywords: Marginal Rate of Return, Net Benefit, Quality, Variety

1. Introduction

Potato ranks first among root and tuber crops in Ethiopia both in volume of production and consumption followed by cassava, sweet potato and yam where smallholder farmers are the major producers as food, and cash crop [1]. Potato is considered as 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 [12]. The global annual production is about 381.7 million tons [13]. In 2013, the Africa's potato production reached over 30 million tons [14]. Soil fertility status and management are among other factors that limit the yield potential of various crops including potato [15]. Potato is naturally a heavy feeder crop. Potato has high phosphorus requirement for optimum growth and yield; thus, when grown on phosphorus deficient soils, considerable yield losses are apparent [16]. In Ethiopia, majority of potatoes produced are used for preparation of different kinds of traditional foods. Recently, however, small-scale potato processors are flourishing in cities and big towns. These require a supply of raw materials with specific internal attributes and regular tuber size (e.g. for the production of French fries and chips, tubers must have a high specific gravity). So far many improved potato cultivars have been developed and widely used for commercial purpose all over the country. In developing countries these varieties much emphasis was given to productivity per unit area and late blight reaction while less emphasis was given to quality.

Oromia National Regional State is a leading producer where potato is used as co-staple food in some zones, such as East Hararghe, Northern region and Central highlands of Oromia region. The average yield of potato is about 19.3 t ha^{-1} [2], which is by far higher than national average yield of 12.66 t ha^{-1} in 2015 [1], but not reach to the crop potential (40 t ha^{-1}) at research centres.

Shiferaw, [3] reported that Ethiopian soils lack most of the macro and micronutrients that are required to sustain optimal growth and development of crops. The soils in central highlands of Oromia region were identified deficient not only nitrogen and phosphorus but also sulfur and Boron [4]. This indicates that the application of nitrogen and phosphorus do not satisfy the nutrient requirements of the crops including potato. It has been also reported that the fertilizer rates used in Ethiopia are below international and regional standards.

To avert the situation, the Ministry of Agriculture of Ethiopia has been recently introduced a new blended NPSB fertilizer containing nitrogen, phosphorous, sulfur and Boron with the ratio of 19%N, 38%P_2O_5, 7%S and 0.1%B. This fertilizer is used as a substitute of DAP in crop production system as main source of phosphorous [5].

In central highlands of Oromia region, particularly at Degam districts, evaluation of blended NPSB fertilizer rate on tuber quality related traits and economic feasibility of potato varieties resistant to late blight has not been studied.

Moreover, information on the performance of varieties in relation to their tuber quality and economic feasibility at Degam woreda, central highlands of Oromia region was not known due to lack of research in the area. For quality potato tuber production and its economic effectiveness in the area, it is essential to evaluate the fitness of the released cultivars in terms of quality under the agro-ecological condition of the area and to incorporate quality as a yardstick in variety selection procedure for growers in the area. Hence, this study was initiated to evaluate quality of some released potato varieties and to know its economic feasibility at Degam woreda of Oromia region.

2. Materials and Methods

2.1. Description of the Study Site

The experiment was conducted at Degam district Central highlands of Oromia regional state June 2013 during cropping season. Degam; district is part of central highlands of Oromia region which is located 124km from Addis Ababa. It is located at about 38°29′to 38°34′East longitude and 9°34′ to 100°03′North latitude and at an elevation of 2878 m.a.s.l. receiving an annual rainfall of 900 to 1400mm. The experimental area is with mean annual minimum and maximum temperature of 15 and 22°, with sandy loam soil and is one of the major potato producing districts.

2.2. Treatments and Experimental Design

The experiment was consisted of three potato varieties (Belete, Gudane and Jalane) and seven rates of blended NPSB fertilizer (0, 50, 100, 150, 200, 250 and 300 kg ha^{-1}). The rates of blended NPSB fertilizer were arranged as the substitute of DAP fertilizer at the rate of 200 kg (92 kg P_2O_5) ha^{-1} that was used for potato production as recommendation of central highlands of Oromia region. The experimental design was randomized complete block design (RCBD) with three replications. Each treatment combination was assigned in one plot of each replication with the plot size of 3.60 x 4.50 meters (16.2 m^2). The spacing between plants in a row and between rows was 0.3 and 0.75m, respectively, in which one plot was consists of six rows each with 12 plants and a total of 72 plants per plot. Well sprouted seed tubers of potato were planted at the spacing of 75 cm between rows and 30 cm between plants. The spacing between plots and blocks was one meter and one and half meters, respectively. Other cultural practices like weeding, earthing up, and plant protection methods are done uniformly for all experimental plots as recommendation for the crop [6].

2.3. Data Analysis

All the measured parameters are subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Linear Model (GLM) of Gen Stat 16th edition [7] and the interpretations was made following the procedure described by Gomez and Gomez, (1984). Least Significance Difference (LSD) test at 5% probability level was used for mean comparison following the significant differences results from the ANOVA.

2.4. Tuber Quality Parameters

Tuber dry matter content (%): five fresh tubers were randomly selected from each plot and washed, weighed and sliced at harvest, sun dried for seven days and further dried in an oven at 75°C for 48 hours until a constant weight will be obtained. Finally, dry matter percent was calculated according to the formula given by William and Woodbury, (1968).

$$\text{Dry matter (\%)} = \frac{\text{weight of sample after drying (g)}}{\text{initial weight of sample (g)}} x100$$

Specific gravity of tubers (gcm^{-3}): This was determined by the weight in air/weight in water method. Five kg tubers of all shapes and sizes were randomly taken from each plot. The selected tubers were washed with water. The samples were then be first weighed in air and then re-weighed suspended in water. Specific gravity was then calculated using the following formula [8]. Specific gravity of tubers (gcm^{-3}) was determined using the method described by Fong and Redshaw, (1973) as:

$$\text{Specific Gravity} = \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}} \text{x100}$$

Total starch content (g/100 g): Percentage of starch in tubers was calculated from the specific gravity where specific gravity. Starch (% or g/100 g) =17.546 +199.07 × (specific gravity-1.0988) (Smith and Talburt, 1959 as cited by Yildrim,

and Tokuşoğlu, 2005).

2.5. Partial Budget Analysis

Partial budget analysis was carried out as per the methodology described [9]. Data like, cost incurred for buying blended NPS and Urea fertilizers labor cost for application of fertilizers, cultivation and harvesting and the price of the marketable yield of potato varieties after harvest was taken in to account to undertake cost-benefit analysis. The partial budget analysis was generally carried out on the basis of the formula developed by [9] as follows.

Gross average tuber yield (kg ha^{-1}) (AvY): is an average yield of each treatment.

Adjusted yield (AjY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

$$AjY = AvY - (AvY*0.1)$$

Gross field benefit (GFB): It was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield.

$$GFB = AjY*\text{field/farm gate price for the crop}$$

Total cost: is the cost of fertilizers and other treatments for the experiment. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, and harvesting was considered remain the same or considered as insignificant among treatments.

Net benefit (NB): was calculated by subtracting the total costs from gross field benefits for each treatment.

$$NB = GFB - \text{total cost}$$

Marginal rate of return (MRR%): was calculated by dividing change in net benefit by change in cost.

Where; MRR = Marginal rate of return in percent, ΔNB and ΔTC= change in net benefit and change in total cost, respectively.

3. Result and Discussion

3.1. Tuber Quality Related Traits

The analysis of variance result revealed that both the main effect of blended NPSB rate and variety and their interaction were not significantly influenced dry matter, specific gravity and starch content of potato tubers (Table 1). The result was in agreement with the findings of that observed non-significant reduction in percent dry matter of tubers due to increased P_2O_5 application [10]. Phosphorus fertilization did not significantly influence tuber specific gravity and dry matter content [11].

3.2. Partial Budget Analysis

The application of highest rates of 300 kg ha^{-1} NPSB fertilizer produced the higher marketable yield of 37290, 35820 and 19096 kg ha^{-1} from Gudane, Belete and Jalane varieties, respectively. The highest marginal rate of return (MRR) of 18.02 (1802.35%) followed by 15.88 (1587.78%) and 14.34 (1434.17%) obtained from Gudane variety with the application of 50, 150 and 300 kg ha^{-1} NPS fertilizer, respectively. The lower MRR of 10.97 (1097.1%) obtained from Gudane with the application of 250 kg ha^{-1} NPS fertilizer. The tubers production of Belete with the application of 300 and 250 kg ha^{-1} NPS fertilizer had MRR of 7.6 (760.27%) and 6.81 (680.91%), respectively. The lowest MRR of 2.07 (207.11%) obtained from Belete variety with application of 200 kg ha^{-1} NPS fertilizer. On the other hand, <1 (100%) MRR was obtained from Jalane with the application of 100, 150 and 200 kg ha^{-1} NPS fertilizer. The MRR of 1.09 (109.09%), 1.35 (135.1%) and 4 (400.15%) obtained from Jalane with 250, 50 and 300 kg ha^{-1} NPS fertilizer, respectively (Table 1). The results of cost benefit analysis indicated that the farmers could be obtained a minimum and maximum of 2.07 and 18.02 Birr, respectively, from Gudane and Belete varieties when farmers cost 1 Birr for fertilizer purchasing. This suggested that the application of fertilizer on the two varieties was acceptable since if farmers obtained additional 1 Birr (100%) from the input cost 1 Birr. (However, the application of 100-200 kg ha^{-1} NPSB fertilizer on Jalane variety did not satisfy farmers since the farmers could not obtain additional 1 Birr (100%) by 1 Birr cost of the application of NPSB fertilizer.

The benefit-cost ratio of Gudane variety with all rates of NPSB fertilizer not lower than the benefit-cost ratio of the variety without application of fertilizer, however, the benefit-cost ratio of Belete and Jalane varieties with all rates of NPS fertilizer was lower than the benefit-cost ratio of the varieties without application of fertilizer (Table 1). The highest MRR of 18.02 (1802.35%) was also obtained from Gudane variety with the application of the lowest rate (50 kg ha^{-1}) of NPSB fertilizer suggested the production of tubers from Gudane variety with lowest rate of fertilizer application seem benefit more than other rates of fertilizer application and production of the other two varieties. However, the producers not only focused the maximum MRR by introducing new technologies but also the magnitude of net benefit (NB). In this regard the highest NB of 166175.5 Birr ha^{-1} was computed for Gudane variety with the application of highest NPSB fertilizer rates of 300 kg ha^{-1}, the second and third higher NB of 158899 and 149658.5 Birr ha^{-1} obtained from Belete with the application of 300 and 250 kg ha^{-1} NPSB fertilizer, respectively.

The relationship between the application of NPSB fertilizer (kg ha^{-1}) and net benefit (Birr ha^{-1}) obtained from three potato varieties indicated that as the rates of fertilizer increased so did the magnitude of net benefit from Gudane and Belete varieties. The magnitude of net benefit from Gudane and Belete varieties was determined by the application of NPSB fertilizer. The net benefit obtained from Gudane and Belete varieties was determined by about 72.06 (R^2=0.07206) and 81.92% (R^2=0.08192), respectively, with the application of NPSB fertilizer. However, the net benefit obtained from Jalane variety was determined by about 35.79% (R^2=0.03579). The net benefit obtained from

Gudane and Belete varieties and application of NPSB fertilizer had positive and strong correlation (r=0.8489 & r=0.9051) and the relationship was linear and significant, but this is not true in the production of Jalane variety (Table 1). The highest NB of 166175.5 Birr ha^{-1} followed by 158899 Birr ha^{-1} was computed from Gudane and Belete varieties, respectively, with the application of highest NPSB fertilizer rate of 300 kg ha^{-1}. The two varieties; Gudane and Belete also had acceptable MRR of 1434.17 and 760.27%, respectively, with the application of highest NPSB fertilizer rate of 300 kg ha^{-1}. Therefore, the growing of Gudane and as second option Belete variety with the application of highest NPS fertilizer rate could be recommended in the study area. According to CIMMYT (1988), the minimum acceptable marginal rate of return should be between 50% and 100%. The current study indicated that the marginal rate of return was found to be >207.11% for all treatment combinations of NPSB fertilizer rates (50-300 kg ha^{-1}) with Gudane and Belete varieties and the chance of obtaining higher net benefit (Birr) was towards to higher rates of fertilizer. This suggested the production of tubers from these two varieties at higher rates of NPSB fertilizer could be attractive for producers because of the high economic returns.

Table 1. *Partial budget analysis of seven rates of blended NPSB fertilizer in combination with three potato varieties at Degam in 2020.*

Blended NPPS (kg ha^{-1})	Variety	AMTY (kg ha^{-1})	AdMTY (kg ha^{-1})	GFB (Birr)	TVC (Birr)	NB (Birr)	MRR	MRR (%)	BCR
0	Gudane	17423.333	15681	86245.5	12000	74245.5			6.19
50	Gudane	29183.333	26265	144457.5	15060	129397.5	18.02	1802.35	8.59
100	Gudane	27616.667	24855	136702.5	15670	121032.5	12.75	1274.85	7.72
150	Gudane	32016.667	28815	158482.5	16280	142202.5	15.88	1587.78	8.73
200	Gudane	31630	28467	156568.5	17190	139378.5	12.55	1254.97	8.11
250	Gudane	31450	28305	155677.5	17800	137877.5	10.97	1097.10	7.75
300	Gudane	37290	33561	184585.5	18410	166175.5	14.34	1434.17	9.03
0	Belete	24680	22212	122166	12000	110166			9.18
50	Belete	26680	24012	132066	15060	117006	2.24	223.53	7.77
100	Belete	27690	24921	137065.5	15670	121395.5	3.06	305.98	7.75
150	Belete	29760	26784	147312	16280	131032	4.88	487.52	8.05
200	Belete	27900	25110	138105	17190	120915	2.07	207.11	7.03
250	Belete	33830	30447	167458.5	17800	149658.5	6.81	680.91	8.41
300	Belete	35820	32238	177309	18410	158899	7.60	760.27	8.63
0	Jalane	12620	11358	62469	12000	50469			4.21
50	Jalane	14073.333	12666	69663	15060	54603	1.35	135.10	3.63
100	Jalane	1336.333	12027	66148.5	15670	50478.5	0.00	0.26	3.22
150	Jalane	11173.333	10056	55308	16280	39028	-2.67	-267.31	2.40
200	Jalane	14696.667	13227	72748.5	17190	55558.5	0.98	98.06	3.23
250	Jalane	15070	13563	74596.5	17800	56796.5	1.09	109.09	3.19
300	Jalane	19096	17187	94528.5	18410	76118.5	4.00	400.15	4.13

4. Summary and Conclusion

The production of potato in Ethiopia is in increasing trend where it is concentrated mostly in mid altitudes and highlands of the country. The sources of plant nutrients for Ethiopian agriculture over the past five decades have been limited to Urea and Diammonium Phosphate (DAP) fertilizers which contain only nitrogen and phosphorus. Ethiopian soils lack most of the macro and micronutrients that are required to sustain optimal growth and development of crops. The soils in central highlands of Oromia region also identified deficient not only nitrogen and phosphorus but also sulfur and boron. This indicates that the application of nitrogen and phosphorus do not satisfy the nutrient requirements of the crops including potato. Therefore, the research was conducted in the area to assess the response of potato varieties to the newly introduced blended NPSB fertilizer to determine its quality and economic profit from the production of potato varieties.

Three potato varieties, namely Gudane (CIP-384321.3), Belete (CIP-393371.58) and Jalane were used in this experiment in 2020 cropping season as experimental material. Seven rates of blended NPSB fertilizer (0, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) was used. The experiment was tested in factorial arrangement in randomized block design with three replications. The experiment was conducted at Boneya, central highlands of Oromia region during 2020 main cropping season.

All quality parameters (dry matter, specific gravity and starch content) were not significantly affected by neither main effect of both factors or the interaction of two factors. The economic analysis revealed that, the application of highest rates of 300 kg ha^{-1} NPSB fertilizer produced the higher marketable yield of 37290, 35820 and 19096 kg ha^{-1} from Gudane, Belete and Jalane varieties, respectively. The relationship between the application of NPSB fertilizer (kg ha^{-1}) and net benefit (Birr ha^{-1}) obtained from three potato varieties indicated that as the rates of fertilizer increased so did the magnitude of net benefit from Gudane and Belete

varieties. The net benefit obtained from Gudane and Belete varieties was determined by about 72.06 (R^2=0.07206) and 81.92% (R^2=0.08192), respectively, with the application of NPSB fertilizer. However, the net benefit obtained from Jalane variety was determined by about 35.79% (R^2=0.03579). The net benefit obtained from Gudane and Belete varieties and application of NPSB fertilizer had positive and strong correlation (r=0.8489 & r=0.9051) and the relationship was linear and significant, but this is not true in the production of Jalane variety.

The highest NB of 166175.5 Birr ha^{-1} followed by 158899 Birr ha^{-1} was computed from Gudane and Belete varieties, respectively, with the application of highest NPSB fertilizer rate of 300 kg ha^{-1}. The two varieties; Gudane and Belete also had acceptable MRR of 1434.17% and 760.27%, respectively, with the application of highest NPSB fertilizer rate of 300 kg ha^{-1}. Therefore, the growing of Gudane and as second option Belete variety with the application of highest NPSB fertilizer rate could be recommended in the study area.

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