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Growth and Productivity of Irish Potato (*Solanum tuberosum* L.) as Influenced by Different Rates of Blended NPSB Fertilizer at Mid-Altitudes of Eastern Guji Zone, Southern Ethiopia

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***Abstract* – Potato (*Solanum tuberosum* L.) is the world's most important root and tuber crop worldwide. Similarly potato is an important food and cash crop in southern Ethiopia including Adola rede District. The field trial was conducted to determine the effect of different application rates of NPSB fertilizers on growth, yield and yield components of potato and to identify their economically appropriate rates that maximize yield of the crop. Irish Potato variety Zemen was used for the study. The design used was one way Anova arranged in a Randomized Block, replicated three times. The treatments used consisted of the combinations of four levels of four levels of P (0, 54, 72, and 90 kg/ha) or NPSB (0, 150, 200, 250). Analysis of variance revealed that application of different blended NPSB rates had a significant effect on all traits except that a non-significant effect on days to 50% flowering and maturity. The maximum (80.28 cm) plant height of the plant of potato tended to increase by increasing dose of 250 kg ha^{-1} fertilizers NPSB. And the minimum (71.01 cm) height of the plant was measured by control treatment. The maximum (12.49) total tuber number per hill was obtained from plots that receive 250 kg NPSB ha^{-1} fertilizer rates. And also the largest average tuber fresh weight per plant (85.47 g) was recorded on 250 kg NPSB ha^{-1} fertilizer rate, while the smallest amount of average fresh tuber weight per hill (72.71 g) was recorded on unfertilized potato plot. The highest marketable and total tuber yields of 20.74 and 23.59 t ha^{-1}, respectively were obtained with the application of 250 kg ha^{-1} NPSB fertilizer. Moreover, the maximum net benefit of Birr 350330 ha^{-1} with an acceptable marginal rate of returns (MRR) of 14500.82% was obtained from treatment that received the application of 150 kg ha^{-1} blended NPSB fertilizer rates could be recommended for production of potato in the study area.**

***Keywords* – Application, MRR, NPSB, Potato, Rate, Tuber, Treatment.**

I. INTRODUCTION

Potato is an economically important staple crop prevailing all across the world with successful large-scale production, consumption, and affordability with easy availability in the open market. Potato has been introduced in to Ethiopia in 1859 by a German Botanist called *Schimper.* Since then, potato has become an important tuber crop in many parts of Ethiopia and it ranks first among root and tuber crops both in a volume of production and consumption followed by cassava, sweet potato, and yam where smallholder farmers are the major producers as food, and cash crop (FAO, 2017).

In Ethiopia, potato production reached 9.689 million tons from 69,610 hectares in 2017/18 cropping season as compared to 974 thousand tons from 16,000 hectares in 2001 and the number of households growing increased from 1.15 million in 2001 to over 1.19 million in ‘‘*meher*’’ 2017/18 (FAO, 2017). Despite high potential production environments and marked growth, the national average potato yield in farmer's field in Ethiopia is only 13.92 t ha^{-1}, which is lower than the experimental yields of over 38 t ha^{-1} done at Holeta agricultural resear-

-ch center and the world average of 19 t ha^{-1} (Tesfaye and Yigzaw, 2008).

In Ethiopia, potato is one among the most important crops as a source of food and cash in the country (Adane *et al.*, 2010). Annual potato production in Ethiopia has increased from 349,000 tons in 1993 to around 743, 153 tons in 2018 (FAOSTAT, 2020) and can potentially be grown on about 70% of arable land in the country (CSA, 2008/2009; Gebremedhin *et al.*, 2008). However, the average yields of potato in African are 6 to 12 tons per hectare; compared to 35-45 tons ha^{-1} in Europe and North America (CIP, 2017) and specifically, in Ethiopia, it is 7.97 tons ha^{-1} (CSA, 2016) which is far below the potential of the crop (CIP, 2017). Inappropriate agronomic practices, shortage of seed tubers of improved potato varieties, soil nutrient depletion, moisture stresses, diseases and insect pests are the major constraints of potato production in the Ethiopia (CIP, 2017; Kefelegn *et al.*, 2012; Tekalign and Hammes, 2005). Additionally Several factors limiting crop yields have been identified by many researchers in Ethiopia; the major ones are lack of stable well-adapted varieties, lack of knowledge in using optimum nutrient supply in every area of production zone, an insufficient supply of disease and insect pests' tolerant varieties. Most Ethiopian soils lack most of the macro and micro nutrients that are required to sustain optimal growth and development of crops (Mulat *et al.*, 1998).

It is obvious that soils are very diverse in terms of inherent and dynamic soil quality. Low soil fertility is one of the limiting factors to sustain potato production and productivity in Ethiopia (Zelleke *et al.*, 2010). Fertilizer recommendations made based on preliminary studies vary across diverse agro ecologies in the country. The fertilizer amount varies with soil type, fertility status, moisture amount, climatic variables, variety, crop rotation and crop management practices (Berihun and Woldegiogis, 2012). In this regard, different reports have been made in determining the optimum fertilizer requirement of potato across the country (Ayichew *et al.*, 2009).

At Adola area, there is an absence of area and variety specific recommendation of fertilizer rates. On the other hand, the soils in the area were identified to be deficient in blended fertilizer NPSB fertilizer which is recommended to substitute P_2O_5 fertilizer in Adola rede District. In addition, this blended fertilizer is under distribution to be applied for all crops. Since the growth, yield and profitability of potato production is largely influenced by the fertility status of the soil and variety selection, so it is necessary to conduct research in the area to identify rate of fertilizer that meets the farmers' interest to obtain high yield, tuber quality and profit. Therefore, the present study was performed to assess the effect of blended NPSB fertilizer on plant growth, tuber yield, and yield-related traits of potato variety, and to estimate economic return of the application of blended NPSB fertilizer at different rates for the production of potato in Adola Rede District.

II. Materials and Methods

2.1. *Description of the Study Sites*

The Experiment was conducted at Bore Agricultural Research Center for two years during summer cropping season at Adola Rede district on-farm location with the aim of identifying the response of Irish potato to the application of different levels of NPSB fertilizers and to identify their economically appropriate rates that maximize yield. The area is located in Guji zone southern Ethiopia estimated 470 km far from Addis Ababa.

2.2. *Description of Experimental Materials and Design and Treatments*

Irish Potato variety zemen was used for the study. The planting material was obtained from seed maintenance.

The selection of the variety was because of that during our evaluation process the variety is basically superior in its yield and adaptability performance at the study areas. The design used was one way Anova arranged in a Randomized Block, replicated three times. The treatments used consisted of the combinations of four levels of four levels of P (0, 54, 72, and 90 kg ha^{-1}) or NPSB (0, 150, 200, 250). The entire rate of P fertilizers was applied at the time of planting. NPSB (18% N+36% P_2O_5 +7% S +0.71% B) was used as fertilizer sources for P and B respectively. The plots size were four rows of each 3 m long with 2.4 m width and medium size and well-sprouted potato tubers were planted at a spacing of 75 cm between rows and 30 cm between plants. Spacing between plots and replications was 1 and 1.5 m, respectively. Agronomic practices such as weeding, cultivation and ridging was applied as per the recommendation of the crop.

2.3. *Data Collection and Analysis*

Days to flowering was recorded when 50% of the plant population attained the flowering stage. Plant height from the sample were determined by measuring height from the base of the main shoot to the apex at full blooming. Number of stems per hill was recorded as the average stem count of five hills per plot reached at flowering stage. Only stems arising from the mother tuber was considered as main stems. Days to physiological maturity was also recorded when the leaves of 70% of the plants in the plot turned yellowish. Tuber number per hill and yield was represented by taking the average yield per plot. Healthy tuber with a size more than or equal to 50 g was considered marketable while rotten, diseased, insect attacked, deformed tuber and those having a weight less than 50 g was categorized as unmarketable. Average tuber fresh weight was recorded by dividing 20 fresh weight of tubers taken from plot by the total number of fresh tubers weighed.

2.4. *Soil Sampling and Analysis*

Initially a soil samples were collected before land preparation from the depth of 30 cm from different parts of the experimental field using auger. Then a composite soil sample was made. After harvested the crop, soil samples were also taken from 0-30cm soils depth for each replications and composited treatment wise. Then a composite soil was analyzed for identifying the soil textural class, pH, CEC, organic carbon, Exchangeable Cation, organic matter, total nitrogen, available Phosphorus, available potassium, Boron and Sulphur.

2.5. *Partial Budget Analysis*

Partial budget analysis was done to determine the relative economic returns on the applied treatments using the prevailing market prices. Finally marginal rate of returns was calculated (MRR), where by percentage change in benefit over change in total variable cost in moving from a lower cost treatment to a higher one.

MRR (%) = Marginal benefit × 100

Marginal Cost

2.6. *Statistical Data Analysis*

The data were subjected to analysis of variance (ANOVA) using Gen-Stat release 18th Edition software (Gen-Stat, 2018). The result interpretations were made following the procedure of Gomez and Gomez and means of significant treatment effects were separated using the DMRT Least Significant Difference (LSD) test at 5% probability level of significance.

III. Results and Discussion

3.1. *Soil Physicochemical Properties of Site before Planting and after crop Harvest*

The analysis of the study site before planting and after harvest for Acidity, Available Phosphorus, Total Nitrogen, Sulfur, Available Potassium, Organic Carbon, Cation Exchange Capacity, Boron, Sodium, Magnesium, Calcium and Texture is indicated below in Table 1 and Table 2.

Table 1. Soil physical and chemical properties of the experimental site before planting.

Soil characters	Values	Examination Standards
pH (by 1: 2.5 soil water ratio)	6.11	ES ISO 10390:2014(1:2.5)
Total nitrogen (%)	0.21	ES ISO 11261:2015(Kjeldahl Method)
Organic carbon (%)	2.81	Walkley and Black Method
C/N ratio	13.38	
Available phosphorous (mg/kg (ppm))	9.27	ES ISO 11261:2015(Olsens Method)
Cation exchange capacity (Meq/100g)	20.26	Ammonium Acetate Method
Calcium		Mehlich-3
Magnesium		Mehlich-3
Sodium		Mehlich-3
Boron		DTPA- D Sorbital
Available potassium (mg/kg (ppm))	209.25	Ammonium Acetate Method
Available sulfur (mg/kg (ppm))	1.46	Turbidometreic
Soil texture:		Bouyoucos Hydrometer Method
Sand	33	
Clay	55	
Silt	12	
Class	Clay	

Source: Tekalign et al. (1991), Berhanu (1980), Moore (2001), Olsen et al. (1954), Jones, J. Benton (2003) and Hazelton and Murphy (2007).

Table 2. Soil physical and chemical properties of the experimental site after crop harvest.

Treatment (kg ha^{-1})		**pH**	**Ava.P**	**SO4-S**	**CEC**	**OC**	**OM**	**TN**	**C:N Ratio**	**Fe**	**Mn**	**Zn**	**Cu**	**B**
NPSB	**N**	**0-14**	**mg/kg**	**mg/kg**	**Meq/100g soil**	**%**	**%**	**%**		**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
0	23	7.11	7.21	9.79	27.79	4.02	6.93	0.29	14.11	24.39	73.69	7.86	5.03	0.54
200	0	7.20	7.21	6.18	27.36	4.15	7.16	0.28	14.78	24.37	113.18	3.67	4.68	0.47
250	69	6.99	7.83	7.21	25.07	4.02	6.93	0.28	14.26	26.82	123.58	5.42	4.97	0.53
250	23	7.14	5.56	14.06	28.06	4.02	6.93	0.28	14.62	23.98	120.74	3.82	4.62	0.48
150	0	7.18	6.39	6.18	29.36	4.02	6.93	0.28	14.41	24.17	104.34	3.53	4.97	0.45

Treatment (kg ha^{-1})		pH	Ava.P	SO4-S	CEC	OC	OM	TN	C:N Ratio	Fe	Mn	Zn	Cu	B
NPSB	N	0-14	mg/kg	mg/kg	Meq/100g soil	%	%	%		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
0	0	7.18	3.30	26.26	28.53	4.02	6.93	0.27	14.78	23.15	100.00	3.52	4.80	0.53
0	69	7.16	3.71	23.69	28.92	3.93	6.78	0.27	14.61	17.95	84.09	3.09	4.53	0.42
150	46	7.10	8.24	18.54	27.09	3.98	6.85	0.28	14.46	21.65	100.06	3.24	4.60	0.41
200	23	7.23	6.59	21.63	28.16	3.93	6.78	0.27	14.61	18.14	48.72	3.15	4.79	0.48
200	69	7.16	4.74	20.60	26.55	3.98	6.85	0.27	14.84	22.82	112.81	4.84	4.61	0.39
200	46	7.13	4.33	22.66	30.28	3.93	6.78	0.26	15.00	28.93	93.17	3.19	4.70	0.42
250	46	7.10	8.24	27.81	26.43	3.62	6.24	0.31	11.75	22.78	79.09	3.39	4.74	0.39
150	69	7.07	6.39	16.48	27.75	3.80	6.55	0.27	14.01	20.75	101.19	3.13	4.73	0.38
250	0	7.03	6.18	21.12	26.18	3.89	6.70	0.26	14.78	20.78	77.90	3.24	4.72	0.41
150	23	7.05	4.53	19.06	27.89	3.84	6.62	0.25	15.49	22.69	102.06	2.91	4.88	0.38
0	46	6.89	3.71	24.72	26.45	3.53	6.08	0.25	14.00	21.17	86.04	2.93	4.77	0.39

3.3. *Phenology and Growth of Irish Potato*

3.3.1. *Days to flowering and maturity*

Analysis of data for different NPSB fertilizer rates revealed non-significant (P>0.05) differences on days to flowering and maturity date (Table 3).

Table 3. Mean values of main effects of days to 50% flowering, maturity date, plant height and stem number as affected by P_2O_5.

NPSB (kg ha^{-1})	Days to Flowering(days)	Days to Maturity (Days)
0	76.75	124.4
150	75.08	124.4
200	75.70	123.4
250	74.59	121.3
Mean	75.5	123.3
LSD (5%)	ns	ns
CV (%)	36.5	26.6

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent.

3.3.2. *Plant Height and Stem Number Per Hill*

The combined data analysis showed that the main effect of NPSB was significant (P<0.05) difference on plant height and stem number of the crop (Table 4). The highest (80.28 cm) plant height of the plant of potato tended to increase by increasing dose of 250 kg ha^{-1} fertilizers NPSB. And the minimum (71.01 cm) height of the plant was measured by control (untreated) treatment. Similarly 250 kg ha^{-1} of NPSB fertilizers recorded maximum (7.91) number of stem number and minimum (6.25) was recorded by zero application. Our data analysis revealed that increasing the rate of NPSB fertilizer increased plant height and main stem number per plant linearly. Application of 250, 200 and 150 kg NPSB ha^{-1} fertilizer rates resulted in significantly higher plant height and main stem number. Increasing the rate of the fertilizer application from 0 to 250 kg NPSB ha^{-1} increased the plant height and main stems number per plant.

Similarly many research work reported that increasing the rate of phosphorus from zero to 230 kg P_2O_5 ha^{-1} resulted in highly significant increases in plant height (Habtamu, 2012). It might be the presence of boron and sulfur in the blended fertilizer nutrient source also significantly increased plant height due to its important role in the cell division and nitrogen absorption from the soil, enhancing plant growth ultimately increased plant height.

Table 4. Mean values of main effects of days to 50% flowering, maturity date, plant height and stem number as affected by P_2O_5.

NPSB (kg ha^{-1})	**Plant Height (cm)**	**Stem Number (Numb.)**
0	71.01^b	6.250^b
150	76.90^a	7.799^a
200	79.12^a	7.594^a
250	80.28^a	7.919^a
Mean	76.82	7.39
LSD (5%)	4.39	1.01
CV (%)	10	23.8

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent.

3.4. *Yield Components and Yield of Irish Potato*

3.4.1. *Total Tuber Number and Average Tuber Weight*

The analysis of variance showed that the main effect of blended NPSB fertilizer and variety and their interaction effect had a significant effect ($p<0.05$) on total tuber number per plant and average tuber weight in gram (Table 5).

Table 5. Mean values of main effects of P_2O_5 on tuber number and average tuber weight.

NPSB (kg ha^{-1})	**Tuber number**	**Tuber Weight (g)**
0	8.35^b	72.71^b
150	11.97^b	81.23^b
200	10.92^b	84.63^{ab}
250	12.49^a	85.47^a
Mean	10.91	81
LSD (5%)	1.74	10.65
CV (%)	17.8	22.9

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent.

The results of analysis of data verify that different NPSB fertilizer rates had significant (P<0.05) effect on tuber number and tuber weight of Irish potato plant. The total tuber number per plant and average tuber weight per tuber (g) were increased with increasing rates of NPSB from zero to 250 bearing 8 tubers to 12 tubers, respectively. The maximum (12.49) total tuber number per hill was obtained from plots that receive 250 kg NPSB ha^{-1} fertilizer rates. However the lowest (8.35) total tuber number per hill was obtained from plots that did not receive fertilizer. More importantly this may be indicated that the increased NPSB rate might have an inhibitory effect on more number of tuber initiation process which increased yield.

The analysis of variance revealed that NPSB fertilizer rates significantly affected the tuber fresh weight per hill of potato (Table 5). The higher average tuber fresh weight per plant (85.47 g) was recorded on 250 kg NPSB ha^{-1} fertilizer rate. Moreover, the maximum rate produced much bigger tubers than untreated plots. The lowest average fresh tuber weight per hill (72.71 g) was recorded on unfertilized potato, but it was not significant difference with potato supplied with 150 and 200 kg ha^{-1} NPSB fertilizer rates.

3.4.2. *Marketable, Unmarketable and Total Yield of Irish Potato*

Marketable tuber yield was significantly (P < 0.05) influenced by the main effects of different NPSB fertilizer rates (Fig. 1). The maximum (20.74 t ha^{-1}) marketable tuber yield was recorded with the main effects of 250 kg NPSB kg ha^{-1} treatment and the least (13.47 t ha^{-1}) marketable tuber yield was recorded at rate of zero NPSB fertilizers application.

Whereas the trend of marketable tuber was in opposite direction to as increasing application of NPSB fertilizer which decreased from zero to 250 kg NPSB ha^{-1} fertilizer application. Increasing the rate of the fertilizer application from 0 to 250kg NPSB ha^{-1}, increased marketable tuber yield by about 35%. Increasing of NPSB fertilizer application rates generally increased marketable yields of the tested potato variety.

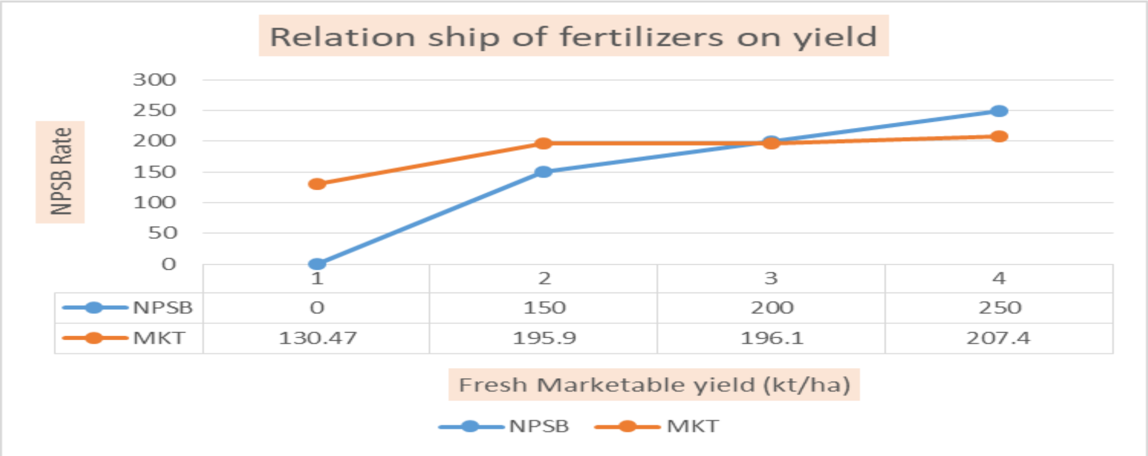

Fig. 1. Main effects of P_2O_5 on marketable tuber yield of Irish potato.

The analysis of variance revealed that different NPSB fertilizer rates significantly affected the unmarketable fresh weight yield of potato (Table 6). The highest unmarketable (2.85 t ha^{-1}) fresh tuber yield were obtained from potato which were supplied with 250 kg ha^{-1} of NPSB fertilizer rate but not significant difference with potato supplied with 150 kg ha^{-1} of NPSB fertilizer rates, recording 2.33 t ha^{-1} of tuber yield. While the lowest unmarketable (1.96 t ha^{-1}) tuber yields of potato were obtained from potato which were not supplied by NPSB fertilizer (Table 6).

Table **6.** Effects NPSB fertilizer rates on Irish potato unmarketable yields

NPSB (kg ha^{-1})	Unmarketable Yield	Total Yield
0	1.964^{b}	15.43^{b}
150	2.113^{b}	21.71^{a}
200	2.336^{ab}	21.95^{a}
250	2.856^{a}	23.59^{a}
Mean	2.31	20.65
LSD (5%)	0.7	2.23
CV (%)	35.1	18.7

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent.

The results of analysis of data verify that main effect of NPSB fertilizer rates had significant ($P<0.05$) effect on fresh total tuber yield of Irish potato plant. The maximum (23.59, 21.71 and 21.95 t ha^{-1}) fresh total tuber yield was recorded with the application of 250, 200 and 150 kg ha^{-1} NPSB fertilizer rates treatment, respectively and the least (15.43 t ha^{-1}) total tuber yield was recorded at rate of zero nutrient application. Increasing the rate of blended NPSB fertilizer from zero to 250 kg ha^{-1} increased total tuber yield. Normally the increase in total tuber yield in response to the increased application of the combined NPSB fertilizers might be due to the increased photosynthetic process and movement of photosynthetic product to the root, which might have helped in the initiation of more tubers on potato.

3.5. *Partial Budget Analysis*

In this study, the costs of fertilizer application, transport, weeding and cost of fertilizers were varied while other costs were constant for each treatment. In order to recommend the present result for farmers, it is important to estimate the minimum rate of return acceptable to beneficiaries in the recommendation base.

The result of the partial budget analysis revealed that the maximum net benefit of Birr 350330 ha^{-1} with an acceptable marginal rate of returns (MRR) of 14500.82 % was obtained from treatment that received the application of 150 kg ha^{-1} blended NPSB fertilizer rates (Table 7). The results of the study indicated that blended NPSB fertilizers had given excellent benefit over the control. Based on this result, 150 kg ha^{-1} blended NPSB resulted in highest adjustable marketable tuber yield of 17.62 t ha^{-1} was more profitable to the farmers in the study area. The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of that change is greater than the minimum rate of return. Therefore the most attractive rates for producers with low input cost of production and higher benefits in this case was 150 kg ha^{-1} blended NPSB and can be recommended for farmers around Adola and other areas with similar agro-ecology.

Table 7. Partial Budget Analysis of NPSB fertilizer rate on Irish potato.

Treatments	Adjusted Yield (t ha^{-1})	Gross Benefit (Br ha^{-1})	Total Variable Cost (Br ha^{-1})	Net Benefit (Br ha^{-1})	Dominance Analysis	MRR
T1	12.123	242460	1500	240960	ND	0
T2	17.629	352580	2200	350380	ND	145.8267

Treatments	Adjusted Yield (t ha^{-1})	Gross Benefit (Br ha^{-1})	Total Variable Cost (Br ha^{-1})	Net Benefit (Br ha^{-1})	Dominance Analysis	MRR
T3	17.651	353020	2600	350420	ND	0.1
T4	18.666	373320	3150	370170	ND	39.68

Where, t = tone, ha = hectare and MRR = marginal rate of return, ND = non-dominant.

IV. Conclusions and Recommendations

In the present study, most growth, yield and yield components of Irish potato were increased with increased application rates of NPSB fertilizer and their responses were significantly different. But all the phenology parameters, like days to flowering and maturity were not affected by the different nutrient application rates. Accordingly, the highest plant height of potato (80.28cm) and maximum (7.92) stem number per plant was recorded on fertilizer rate of 250 kg $ha^{-1}$of NPSB fertilizer rates. In the case of fertilizer rates, the highest (12.49) tuber number per hill and highest (85.47 g) average tuber weight were recorded on potato which was applied with 250 kg $ha^{-1}$of NPSB fertilizer rate. Application of NPSB fertilizer rate of (250 kg ha^{-1}) has significantly and positively increased the marketable, unmarketable and total tuber yield of Irish potato at the study area. The highest (20.74 t ha^{-1}) economic yield was obtained from the application rate of 250 kg ha^{-1}. Therefore, these treatment appeared promising for potato production under the study area. Generally our result of the study revealed that the application of NPSB resulted in better performance in terms of improving yield and yield components of Irish potato yield.

Based on partial budget analysis the highest net benefit 350330 Birr ha^{-1} was obtained from treatment fertilizer application of 150 kg ha^{-1} blended NPSB with a marginal rate of return of 145.83 %. Therefore the most attractive rates for the producers with low cost of production and higher benefits in this case was treatment having rate of 150 kg ha^{-1} NPSB fertilizer. More importantly farmers in the study areas should be need to use recommended nutrient supply to an optimum level for sustaining the intended crop productivity.

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Conflict of Interest

All the authors do not have any possible conflicts of interest.

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