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Effect of blended chemical fertilizer (sulfur, nitrogen and phosphorus) on yield and yield components of potato (*Solanum tuberosum* L.) in the rainy season

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Potato is the fourth most important crop and consumed all around the world and is one of the main favorite vegetable in Ethiopia. However, the national productivity is very low as compared to the potential of the crop. One of the main reason for low productivity is low soil fertility. Hence, a field experiment was conducted from 2016-2018 with 9 combination of nitrogen, phosphorous and sulfur fertilizers arranged in randomized complete block design with three replications to assess response of potato to these rates. The application 110-19.74-50.8 kg·ha^{-1} N_2/S_2 /P_2O_5 fertilizer delayed days to flowering and maturity by 8 and 11 days at Darark and 10 and 14 days at Dabat. However, it increased plant height and number of stems per plant, which may positively contribute to increased photosynthetic area. The application of these fertilizers advanced marketable tuber yield by 153% and the total tuber yield by 86.6% relative to unfertilized plants. Furthermore, the partial budget analysis data showed that the highest net benefit and marginal rate of return (4453.6%) was obtained from 110-19.74-50.8 kg ha^{-1}. Therefore, the current study results is indicative that potato can grow well and provide better yield at Dabat, Dabark and similar agro ecology by using 110-19.74-50.8 kg ha^{-1} N_2/S_2 /P_2O_5, respectively.

Key words: Fertilizer, marginal rate of return, marketable tuber, yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the fourth most economically important crop globally and the first among root and tuber crops (FAO, 2016). It is among high yielder crops in short duration of time (mostly < 120 days) and nutritionally; it is source of energy, minerals, vitamins and dietary fiber (Mulatu et al., 2005; Lutaladio and Castaldi, 2009). Potato was introduced to Ethiopia in 1859 by the German botanist Schimper (Gebremedhin et al., 2008). Its production has increased considerably through time and has contributed greatly for millions of Ethiopians. Hence, it is among the major crops of Ethiopia. North Gondar is one of the major potato production zones in north-western part of Ethiopia (Gebremedhin et al., 2001; Adane et al., 2010).

Though Ethiopia has a favorable climate for potato production, national productivity (13.45 t/ha) is very low (CSA, 2016). Among the limiting factor, low soil fertility is a detriment to sustained agricultural production and

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Table 1. The treatment combinations.

Treatment number	Rate (kg/ha) and type of fertilizer (N_2, S_2, P_2O_5)	Treatment number	Rate (kg/ha) and type of fertilizer (N_2, S_2, P_2O_5)	Treatment number	Rate (kg/ha) and type of fertilizer (N_2, S_2, P_2O_5)
1	Unfertilized (0-0-0)	4	110-0- 0	7	110-19.74-50.8
2	0-0- 90	5	55- 0- 45	8	110- 0- 45
3	55-9.87-25.4	6	55-0- 90	9	110-0- 90

productivity in Ethiopia (Tamirie, 1989). The average nutrient depletion in highlands of Ethiopia, like the present research area, much more than the lowlands (Henao and Baanante, 1999). This is due to the reasons that the area receives high rainfall, creates high runoff and high soil erosion, fixation of phosphorus and leaching in respect of nitrogen and potassium. Also poor culture of the farmer for nutrient replacement through application of micro and macro nutrient, absence of nutrient recommendation specifically for those areas considering the soil and the agroecology are another challenge.

Potato has shallow and inefficient rooting system (Munoz et al., 2005) and crops absorbs huge amount of nutrients from soil per season (Trehan et al., 2005). Fertility status of soil, type, amount and time of fertilizer application has great influence on yield and quality of potato production (Westermann, 2005). Nitrogen, phosphorus, potassium and sulfur are among the elements that are essential for potato production.

Nitrogen is an integral component of many compounds such as chlorophyll, nucleotides, alkaloids, enzymes, hormones and vitamins and these are essential for plant growth processes (Brady and Weil, 2008). Nitrogen is a valuable nutrient for plants and plays an important role in tuber size development but overdose of nitrogen lowers the tuber dry matter (Zelalem et al., 2009). Adequate amount of nitrogen has a positive impact on quality and yield of potatoes. Likewise phosphorus influences plant metabolism through its role in cellular energy transfer, respiration and photosynthesis (Grant et al., 2001). The application of appropriate rate of phosphorus fertilizer increases the tuber yield of potato, however the response will be negative if applied beyond the optimum rate (Sharma and Arora, 1987).

Sulfur is one of 16 essential nutrient elements and fourth major nutrient after NPK, required by plants for proper growth and yield as it is known to take part in many reactions in all living cells (Sud and Sharma, 2002). According to Klikocka (2004), the content of sulfur in potato tubers is on average between 0.7-2.0 g kg^{-1} and its uptake ranges from 18 to 40 kg ha^{-1}. Sulfur enhances starch synthesis in tubers and it is a component of proteins and many enzymes (Lalitha et al., 2002). It increases the resistance of this cultivar of potato to environmental stress and plays an important role in protecting the plants from pests and diseases (Klikocka, 2005). Sulfur deficient plants had poor utilization of nitrogen, phosphorus and potash (Nasreen et al., 2003).

In the study area, farmers utilized inorganic fertilizers for increasing potato yields like Urea as a source of nitrogen and Di-ammonium phosphate (DAP) as a source phosphorous since these are the only fertilizers commercially available in the local market. Currently, the Ethiopian government introduce blended fertilizer for the study and similar agro ecology which has sulfur, nitrogen and phosphorous. However, there was no appropriate fertilizer rate recommendation for potato crop in the study area. Therefore, the study was undertaken to assess responses of potato to Nitrogen, Phosphorous and sulfur fertilizers combination and identify economically feasible fertilizer rate for potato production in the rainy season.

MATERIALS AND METHODS

This study was conducted at Dabat and Dabark District of North Gondar Administrative Zone during 2016-2018 main cropping seasons. Belete (CIP-393371.58) potato variety, obtained from Holeta Agricultural Research Center, Holeta, Ethiopia, with a medium tuber diameter of 40-45 mm were planted on flat land at the beginning of the main rainy season (June). The study area has a clay loom soil which was plowed 3 times using Oxen.

A total of nine treatment combinations of nitrogen sulfur and phosphorous (Table 1) were arranged in randomized complete block design with three replications. Prior to planting, representative soil samples were taken using an auger from the top 0-30 cm and combined into a composite sample. Samples were analyzed in the laboratory using the standard procedure for each of soil pH, organic carbon, total N, available phosphorus, cation exchange capacity (CEC) (Table 2).

Sprouted tubers in the diffused light store (DLS) were planted by hand in rows 75 cm apart and with 30 cm between plants within rows, each experimental plot was 9 m^2 in size. Blocks were separated by 1.5 m. All of the phosphorus and sulfur, half the nitrogen was applied at planting and the remaining nitrogen applied at 45 days after planting. Urea (46%N), blended fertilizer (39%N_2, 18% P_2O_5, 7% S_2) and triple super phosphate TSP (46% P_20_5) fertilizers were used as sources of nitrogen, sulfur and phosphorus. There were 4 rows/plot for each treatment. Data were collected from the middle 2 rows; the outermost rows and terminal plants were borders. Earthening up and weeding were each carried out 3 times by hand during the growing period.

Data were collected on phenological and growth parameters such as days to 50% flowering and maturity, plant heights, number of stem per plant and yield parameters like total tuber number, marketable and unmarketable tuber number, marketable, unmarketable and total tuber yields (t ha^{-1}) and average total tuber

Table 2. Chemical properties of the soil of experimental sites taken before planting.

Parameter	Value at Dabat	Value at Dabark
pH	5.65	5.91
Total nitrogen (%)	0.239	0.192
Available phosphorus (ppm)	10.65	26.91
Organic matter (%)	5.57	4.47
EC ($mS{\cdot}cm^{-1}$)	0.14	0.17
Cation Exchange Capacity ($Cmol_c{\cdot}kg^{-1}$)	43.87	40.44

weight. Data were checked for constant variance and normality and over year combined data were subjected to analysis of variance using SAS Version 9.2 statistical software (SAS, 2008). Treatment means were compared using LSD value at 5% significant level.

Partial budget analysis was employed for economic analysis of fertilizer application using a technique described by CIMMYT (1988). It was carried out for combined tuber yield data. The marketable tuber yield data was adjusted by bringing down 10% to minimize plot management effect by the research or to reflect the actual farm level performance. To estimate the total costs, mean market prices of Urea and NPS, DAP, Cost of fertilizer transportation and labor for application of fertilizer were taken from market assessment at the time of planting and market price of potato tubers was taken after harvest.

RESULTS AND DISCUSSION

Phenological and growth parameters

The results of analysis of variance (ANOVA) showed that NSP fertilizers influenced the days to 50% flowering and maturity. The application of 110-19.74-50.8$N_2/S_2/P_2O_5$ kg/ha at Dabark site delayed days to flowering and maturity by 8 and 11 day, respectively as compared to unfertilized treatment (Table 3). A similar fertilizer rate when used at Dabat, delayed flowering and maturity by 10 and 14 days respectively. Over all combined result of both location and year revealed that application of the same treatment prolonged the flowering and maturity period by 9 and 12 days respectively as compared to none treated one followed by application of 110kg/ha N_2 with 90 P_2O_5 kg/ha. This is due to the fact that, increased concentration of nitrogen fertilizer can increase the nitrogen uptake and this increase contributes to have excessive haulm development for staying longer duration (Mulubrhan, 2004). Such research findings were reported previously by Zelalem et al. (2009) where the application of phosphorous and nitrogen fertilizer significantly delayed days to 50% flowering and maturity. Similarly, Israel et al. (2012) and Melkamu and Minwyelet (2018) reported that application of nitrogen, phosphorous and sulfur fertilizer showed significant effect on prolonging of time of flowering and maturity.

Plant height was significantly influenced by the application of fertilizers (Table 3). The two years combined analysis of the experiment in Dabark and Dabat areas showed that application of 110 kg N_2 with 90 kg ha^{-1} P_2O_5 fertilizer gave the maximum plant height, 70.16 and 64.2 cm while the shortest (47.83 and 42.73 cm) was found from untreated plant, respectively. Here, the fertilizer application resulted in a difference of 22.3 and 21.4cm height respectively as compared to the untreated potato (Table 3). It is true also for the overall combined result that revealed 48.3% height increment as compared to untreated plants. The probable reason for increment in plant height might be due to more uptake of N_2 during growth period resulting in increase in cell size, elongation and enhancement of cell division which ultimately increase the plant growth. The result goes in line with those of Zelalem et al. (2009) who had reported significant height difference (10.5 to 24 cm) and resulted from application of NITROGEN and phosphorous fertilizer. Results of the present experiment are in agreement with the finding of Sharma et al. (2014) who had reported that plant height increased with increasing fertilizer levels of nitrogen and phosphorus. Also, Mojtaba et al. (2013) reported a significant and 23.82% plant height increment due to increasing the level of nitrogen rate 0 to 150 kg-ha^{-1}.

The number of stem per plant was significantly affected by the application of fertilizers (Table 3). The highest number of stems were recorded from application of 110-19.74-50.8 $N_2/S_2/P_2O_5$ kg ha^{-1} and 110 kg N_2/ha with 90 kg/ha P_2O_5 at Dabark and Dabat, respectively whereas the lowest number of stems were from untreated plants. The result of overall combined data showed that an application of 110 kg N_2 with 90 kg/ha P_2O_5 resulted in the maximum number of stems followed by 110-19.74-50.8 $N_2/S_2/P_2O_5$ kg ha^{-1}. This might be due to the fact that fertilization application encouraged more number of independent stems. According to Jamaati-e-Somarin et al. (2009) increasing nitrogen level up to 110 kg/ha increased the stem number; however further increases nitrogen fertilizer level did not affect it any more. Singh et al. (2016) and Melkamu and Minwyelet (2018) reported that nitrogen with sulfur fertilizer resulted in a significant and maximum number of stem per plant.

NPS effects on yield components

Number of marketable, unmarketable tubers and total number of tubers were influenced significantly by the

Table 3. The effect of nitrogen/sulfur/phosphorous on phenological and growth parameter.

N_2, S_2, P_2O_5 kg/ha respectively	Dabark (combined, 2016-2017)				Dabat (combined, 2016-2017)				over all combined result (over location-over year)			
	DTF	DM	Pht	Nstm	DTF	DM	Pht	Nstm	DTF	DTM	Pht	Nstm
0-0-0	58d	117.16^{d}	47.83^{f}	3.41^{e}	56.33^{d}	115.83^{f}	42.73^{e}	3.4^{c}	57.16^{d}	116.5^{e}	45.28^{e}	3.4^{e}
0-0- 90	63.16^{bc}	123.66^{b}	61.7^{c}	4.23^{d}	63.5^{b}	119.33^{e}	53.26^{cd}	4.23^{b}	63.5^{b}	120.58^{d}	54.81^{d}	4.23^{d}
55-9.87-25.4	63.83^{abc}	123.83^{b}	62.8^{c}	5.1^{abc}	62.16^{bc}	124.16^{c}	51.26^{d}	4.68^{b}	62.66^{bc}	123.91^{c}	56.48^{d}	4.87^{bc}
110-0-0	63.66^{abc}	124.16^{b}	61.11^{c}	5.0^{bc}	66.66^{b}	122.67^{dc}	60.23^{ab}	4.8^{b}	63.75^{b}	123.25^{c}	61.51^{bc}	4.9b^{c}
55-0-45	61.5^{c}	120.83^{c}	58.43^{de}	4.73^{cd}	61^{c}	120.66d^{e}	58.26^{bc}	4.8^{b}	61.25c	120.75^{d}	58.35^{cd}	4.76^{c}
55-0-90	63.5^{bc}	124.16^{b}	59.9^{cd}	4.6b^{cd}	63.66^{b}	124^{c}	60.26^{ab}	4.33^{b}	63.66^{b}	120.08^{c}	61.19^{bcd}	4.46^{cd}
110-19.74-50.8	66.67^{a}	128^{a}	66.18^{b}	5.65^{a}	66.66^{a}	130.16^{a}	59.36^{ab}	5^{b}	66.66^{a}	129.08^{a}	62.77^{b}	5.32^{b}
110- 0- 45	63.5^{bc}	121.83^{bc}	56.36^{e}	4.93^{c}	61.83^{bc}	124.66^{c}	62.86^{ab}	4.33^{b}	62.66^{bc}	124.41^{c}	61.38^{bcd}	4.63^{cd}
110-0-90	66.16^{ab}	127a	70.16^{a}	5.6^{ab}	66^{a}	127.33^{b}	64.2^{a}	6.1^{a}	66.08^{a}	127.16^{b}	67.18^{a}	5.95^{a}
CV	4.21	1.66	4.59	11.33	2.62	1.61	8.15	14.9	3.47	1.62	6.78	13.45
Mean	63.33	123.4	60.6	4.8	62.75	123.2	56.94	4.63	63.04	123.3	58.77	4.79
LSD	3.1	2.4	3.26	0.63	1.92	2.32	5.44	0.8	1.78	1.62	3.24	0.51

DTF = days to flowering; DEM = days to maturity; Pht = plant height (cm); Nstm= number of Stem per plant.
*Significant, ** highly significant, LSD =least significant difference, means followed by the same letter(s) are not significantly different.

application of different level and type of fertilizer (Table 4). The two years combined analysis of the experiment at both location and the overall combined result revealed that the maximum number of unmarketable tuber was recorded from unfertilized treatment followed by application of 55 kgha^{-1} N_2 with 45 kg ha^{-1} P_2O_5 whereas the minimum number of unmarketable tuber was recorded from 90 kg ha^{-1} P_2O_5 for Dabark and 110 kg ha^{-1} N_2 for Dabat.

On the other hand, the maximum number of marketable tuber for overall combined result and Dabat area were recorded from application of 110- 90 kg/ha N_2 /P_2O_5 while 110-19.74-50.8 kg/ha N_2/S_2/P_2O_5 for Dabark area. The raise in the application of N_2 0 to 110 kg/ha with 90 kg ha^{-1} P_2O_5 increased the number of marketable tuber by 122% at Dabat (Table 4). Increasing the rate 0 to 110-19.74-50.8 kg ha^{-1} N_2/S_2/P_2O_5 at Dabark increased the number of marketable tuber by 127%. The maximum total number of tubers/plant were recorded from untreated plants for all cases but the minimum number of total tuber at Dabark was from application of 110-45 kg ha^{-1} N_2/P_2O_5 while 90 kg/ha P_2O_5 for Dabat.

It is clear that the increase in number of marketable tuber with increase in applied nitrogen, sulfur and phosphorous was associated with decrease in the number of the small size tubers and increase in the weight of individual tubers. This could be probably due to the fact that marketable tuber number increases at higher nitrogen rate because nitrogen can trigger the vegetative growth for more photo-assimilate production while phosphorous enhanced the development of roots for nutrient uptake. According to Israel et al. (2012), application of nitrogen from 0 -165 kg N ha^{-1} and phosphorus from 0 - 60 kg P_2O_5 ha^{-1} increases marketable tuber number by 56.36 and 19.2% respectively as compared to control. Similarly, Singh et al. (2016) reported that application of 180 kg N_2 along with 50 kg S_2 increase the number of tuber by 43%. Rosen and Bierman (2008) reported that application of phosphorus fertilizer had significant contribution to increase total tuber yield and total number of tubers per plant as compared to unfertilized.

NPS effect on potato tuber yield

The application of different type and rate of fertilizer significantly influenced the marketable, unmarketable and total tuber yield (Table 5). The result of the two years combined analysis of the experiment in Dabark areas showed that a

Table 4. The effect of nitrogen/sulfur/phosphorous on number of tubers/plant.

N_2, S_2, P_2O_5 kg/ha respectively	Dabark (combined, 2016-2017)			Dabat (combined, 2016-2017)			Combined result (over location-over year)		
	UMTN	MTN	TTN	UMTN	MTN	TTN	UMTN	MTN	TTN
0-0-0	13.58^{a}	3.63^{f}	17.21^{a}	13.86^{a}	3.81^{f}	17.68^{a}	13.72^{a}	3.72^{e}	17.45^{a}
0-0- 90	6.23^{dc}	5.68^{de}	11.91^{de}	4.53^{def}	6.2^{cdr}	10.73^{c}	5.38^{cde}	5.94^{c}	11.32^{e}
55-9.87-25.4	4.85^{d}	6.91^{bc}	11.7^{6e}	5.4^{d}	5.63^{e}	11.03^{c}	5.12^{cde}	6.27^{bc}	11.47^{de}
110-0-0	6.2^{cd}	7.63^{ab}	13.83^{bc}	3.71^{f}	7.51^{ab}	11.23^{c}	4.95^{de}	7.57^{a}	11.53^{cd}
55- 0-45	9.86^{b}	5.21^{e}	15.08^{b}	8.95^{b}	4.23^{f}	13.18^{b}	9.4^{b}	4.72^{d}	14.13^{b}
55-0- 90	6.8^{c}	6.83^{bc}	13.68^{bcd}	5.26^{de}	6.71^{bcd}	11.98^{bc}	6.05^{cd}	6.77^{b}	12.83^{c}
110-19.74-50.8	5.38^{cd}	8.25^{a}	13.63^{bcd}	$4.88d^{ef}$	7.13^{bc}	12.01^{bc}	5.13^{dce}	7.69^{a}	12.82^{c}
110- 0-45	5.13^{cd}	6.48^{cd}	11.61^{e}	7.2^{c}	6^{de}	13.2^{b}	6.16^{c}	6.24^{bc}	13.40^{cde}
110-0-90	5.06^{d}	7.73^{ab}	12.8^{cde}	3.85^{ef}	8.46^{a}	$12.31b^{c}$	4.45^{e}	8.10^{a}	12.55^{cd}
CV	21.44	14.64	11.6	20.24	13.38	10.91	19.58	14.04	11.35
Mean	7.01	6.48	13.5	6.4	6.19	12.59	7.45	6.33	13.05
LSD	1.76	1.11	1.84	1.61	0.97	1.61	1.13	0.72	1.2

UMTN = number of unmarketable tuber; MTN= number of marketable tuber; TTN= total tuber number.
*Significant, **highly significant, LSD =least significant difference, means followed by the same letter(s) are not significantly different.

Table 5. The effect of nitrogen/sulfur/phosphorous on yield.

N_2, S_2, P_2O_5 kg/ha respectively	Dabark (combined, 2016-2017)				Dabat (combined, 2016-2017)				Combined result (over location-over year)			
	UMTY	MTY	TTY	AWtT	UMTY	MTY	TTY	AWtT	UMTY	MTY	TTY	AWtT
0-0-0	6.65^{a}	12.4^{e}	19.05^{d}	26.48^{f}	7.13^{a}	11.96^{d}	19.05^{d}	26.24^{f}	6.89^{a}	12.15^{f}	19.05^{e}	26.36^{e}
0- 0- 90	5.58^{ab}	19.75^{cd}	25.33^{c}	48.03^{cde}	4.11^{f}	21.88^{b}	$26b^{c}$	54.73^{bcd}	4.85^{bc}	20.81^{d}	25.66^{c}	51.38^{bc}
55-9.87-25.4	3.5^{e}	22.53^{bc}	26.03^{c}	49.47^{bcd}	5.55^{bcd}	21.95^{b}	27.5^{bc}	$56.38b^{c}$	4.52^{c}	22.24^{cd}	26.76^{c}	52.92^{b}
110-0- 0	4.21^{cde}	23.35^{b}	27.56^{c}	45.15^{de}	4.16^{ef}	22.86^{b}	27.03^{bc}	54.51^{bcd}	4.19^{c}	23.1^{c}	27.3^{c}	49.83^{bc}
55-0- 45	4.73^{bcd}	16.65^{d}	21.38^{d}	31.69^{f}	6.45^{ab}	18.18^{c}	24.7^{c}	41.93^{e}	5.59^{b}	17.41^{e}	23.0^{d}	36.81^{d}
55- 0-90	5.18^{bc}	20.08^{c}	25.26^{c}	41.66^{e}	5.96^{bc}	21.73^{c}	27.7^{b}	52.28^{cd}	5.57^{b}	20.9^{d}	26.48^{c}	46.97^{c}
110-19.74-50.8	5.15^{bC}	30.26^{a}	35.41^{a}	58.99^{a}	4.46^{def}	31.37^{a}	35.5^{a}	67.59^{a}	$4.8b^{c}$	30.74^{a}	35.55^{a}	63.29^{a}
110 0-45	$3.7d^{e}$	23.73^{b}	27.43^{c}	$53.1a^{bc}$	5.28^{cde}	22.18^{c}	27.46^{bc}	47.62^{de}	4.49^{c}	22.95^{cd}	27.45^{c}	50.36^{bc}
110-0-90	3.61^{de}	27.95^{a}	31.56^{b}	55.64^{ab}	4.73^{def}	28.32^{a}	33.01^{a}	61.07^{ab}	4.17^{c}	28.11^{b}	32.29^{b}	58.35^{a}
CV	21.5	12.27	9.79	12.43	18.3	11.6	9.23	12.34	20.58	12.07	9.44	12.68
Mean	4.7	21.85	26.56	45.59	5.31	22.24	27.34	51.3	5.01	22.05	27.04	48.44
LSD	1.19	3.14	3.05	6.64	1.14	3.02	2.98	7.44	0.86	2.16	2.08	5

UMTY = yield of unmarketable tuber; MTY= Yield of marketable tuber; TTY= total tuber yield;AWtT= Average weigh of total tuber. *Significant, ** highly significant, LSD =least significant difference, means followed by the same letter(s) are not significantly different.

a minimum unmarketable tuber yield was recorded from application of 55-9.87-25.4 kg/ha $N_2/S_2/P_2O_5$, while the maximum unmarketable yield was measured from unfertilized treatment (Table 5). On the contrary, the lowest marketable tuber yield (12.4 t ha^{-1}) was recorded from untreated and the maximum marketable tuber yield (30.26 t ha^{-1}) was from application of 110-19.74-50.8 kg $ha^{-1}N_2/S_2$ $/P_2O_5$. Similarly, at Dabat site a maximum unmarketable yield (7.13 t ha^{-1}) and a minimum marketable tuber yield (11.96 t ha^{-1}) were recorded from untreated plant, while the maximum marketable tuber (31.37t ha^{-1}) was from 110-19.74-50.8kg $ha^{-1}N_2/S_2$ $/P_2O_5$. This indicated that as the rate of fertilizer increased the size of the tuber increased which might be due to initiation of more vegetative growth that resulted production of more photo-assimilate to be translocated to the tubers and decreased the number and yield of unmarketable tubers (Grant et al., 2001; Nasreen et al., 2003; Brady and Weil, 2008).

The overall combined data showed that increased level of nitrogen and phosphorous fertilizer from 0 to 110 N_2 with 90 kg ha^{-1} P_2O_5 increased the marketable yield by 131% (Table 5). Moreover, addition of 20 kg sulfur over this (110-90 N_2 $/P_2O_5$) raised the marketable yield by 153%. Similarly, the overall combined result revealed that 86.6% total yield increment was due to increase in the application of 0 to 110-19.74-50.8 kg $ha^{-1}N_2/S_2$ $/P_2O_5$ followed by 69.5% from application of 110 kg N_2 with 90 kg P_2O_5 ha^{-1}. Even application of 9.87 kg $ha^{-1}S_2$ with 55-25.5 kg $ha^{-1}N_2$ P_2O_5 increased the total yield by 40.47%. The probable reason for increased in tuber yield with increasing sulfur levels might be attributed to its role in better partitioning of the photo-assimilates in the shoot and tubers (Sud and Sharma, 2002). Another probable reason might be due to addition of phosphorus which enhances development of roots particularly lateral and fibrous rootlets which in turn contributed in nutrient absorption, photosynthesis and general physiological processes. According to the report of Mahmoodabad et al. (2010) and Sharma and Arora (1987), increment of nitrogen fertilizer rate resulted in more tuber yield but excessive rate of nitrogen (250 kg ha^{-1}) and decreased the total number of tubers per unit area and yield, since high amount of nitrogen encourage vegetative growth more than tuber growth.

The present investigation is in line with those of Singh et al. (2016) that reported application of nitrogen and sulfur fertilizer resulted a significant increment on marketable and total tuber yield. Similarly, Sharma et al. (2011) reported that application of sulfur fertilizer resulted significant differences on yield and raising the level 0 to 45kg/ha increased total tuber yield per plant by 32.55%. Also, Zelalem et al. (2009) reported similar response of potato with application of nitrogen and phosphorous fertilizers.

In the present study, the type and rate of fertilizer significantly affected average weight of a tuber. The minimum average weight of tuber at both locations was obtained from unfertilized treatment. The overall combined result reveal that application of 110-19.74-50.8 kg/ha N_2/S_2 $/P_2O_5$ provided the maximum average tuber weight (63.29 gm/tuber) followed by 110-90 kg $ha^{-1}N_2/P_2O_5$. Moreover, application of 9.87 kg ha^{-1} S_2 with 55-25.4kg $ha^{-1}N_2/P_2O_5$ doubled the size of average tuber weight as compared with unfertilized plant. The current result is in conformity with the work of Israel et al. (2012) who reported an increase in nitrogen and phosphorous fertilizer revealed significant contribution to increase in total tuber yield and advanced to get larger average tuber weight. Similarly, Barczak et al. (2013) reported that sulfur fertilizer contributed for a significant increment of potato tuber yield through enlarging tuber weight during a three-year research.

Partial budget analysis

As indicated in Table 6, except treatments combinations of 0-0-0, 55-9.87-25.4, 110-0-0 and 110-19.74-50.8 N-S-P Kg ha^{-1}, all the other treatments were dominated. This means the net benefit that was obtained from these treatments was lower than the net benefit obtained from the treatments with lower variable cost and there was no proportional increment in the net benefit with increase in variable cost.

The partial budget analysis revealed that application of nitrogen, sulfur and phosphorous fertilizer gave the high gross profit, net return and marginal rate of return compared to the control. The highest net benefit (134,500 birr/ha) and marginal rate of return (4453.6%) were obtained from the combination of the tree nutrient application at the rate of 110-19.74-50.8N-S-P Kg ha^{-1} followed by 55- 9.87- 25.4 N-S-P Kg ha^{-1} which had 2264.8% marginal rate of return. The results showed that the rate of 110 Kg ha^{-1} with 90 Kg ha^{-1} were dominated (D) by 110-19.74-50.8N-S-P Kg ha^{-1} indicating that the former level and composition of treatment was less profitable than the later. The fertilizer rates of 110-19.74-50.8 N-S-P Kg ha^{-1} was proved to be the superior and economically viable for potato production that can be recommended for farmers in the area.

Conclusion

The two-year and two location research showed that the application of nitrogen, sulfur and phosphorous significantly increased the potato tuber yield as compared to the control. Application of 110-19.74-50.8 kg/ha N_2/S_2 $/P_2O_5$ fertilizer delayed days to flowering and days to maturity by 8 and 11 days at Darark and 10 and 14 days at Dabat, respectively. However, it had positive and significant effect to increase plant height and number of stem per plant, which may have positive contribution to

Table 6. Partial budget analysis data for the combined fertilizer rate.

Treatment combination (Nitrogen-sulfur-phosphorous)	Average Yield (Kg/ha)	Adjusted yield (Kg/ha)	Gross field benefit	cost of Fertilizer	Cost Fertilizer application (Labor)	Cost for fertilizer transport	Total variable cost	Net Benefit	Marginal net benefit	Marginal variable cost	Marginal rate of return
0-0-0	12150	10935	54675	0	0	0	0	54675			
55-9.87-25.4	22240	20016	100080	1650	180	90	1920	98160	43485	1920	2264.8
55- 0- 45	17710	15939	79695	2248	240	110	2598	77097[d]			
0-0- 90	20810	18729	93645	2300	240	120	2660	90985[d]			
110-0- 0	23100	20790	103950	2625	300	150	3075	100875	2715	1155	235.06
55-0- 90	20900	18810	94050	2849	300	150	3299	90751[d]			
110-19.74-50.8	30740	27666	138330	3300	360	170	3830	134500	33625	755	4453.6
110- 0- 45	22950	20655	103275	3346	360	180	3886	99389[d]			
110-0- 90	28110	25299	126495	3398	330	170	3898	122597[d]			

Price of UREA=1050 birr qt^{-1}; NPS =1100 birr qt^{-1}; DAP= 1150 birr qt^{-1}; Field price of Potato = 500 qt^{-1}; d=dominated.

increase size of photosynthetic area. Moreover, overall combined result revealed 153% increment of marketable tuber yield and the total tuber yield by 86.6% as compared to unfertilized. In addition, this rate and type of fertilizer increased the number of marketable tuber by 106.7% and provided lesser yield and number of unmarketable tuber, which has direct economic value for the benefit of the farmers as well as the consumer. On the other hand, the highest marginal rate of return (4453.6 %) was found from this fertilizer combination and rate. Therefore, the current result use of 110-19.74-50.8 kg/ha N_2/S_2 /P_2O_5 provided better yield and can be used at Dabat, Dabark and similar agro ecologies.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Adane H, Miranda PMM, Agajie T, Willemien JML, Alfons OL, Admasu T, Paul CS (2010). Analysis of Seed Potato Systems in Ethiopia. American Journal of Potato Research 87(6):537-552.

Barczak B, Nowak K, Knapowski T (2013). Potato yield is affected by sulphur form and rate. Agrochimica 57(4):363-372.

Brady NC, Weil RR (2008). The nature and properties of soils. 14th ed. Pearson Prentice Hall, NJ.

CIMMYT (1998). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. D.F.Maxico.

Central Statistical Agency (CSA) (2016). Agricultural sample survey on crop and livestock product utilization. Statistical Agency, The Federal Democratic Republic of Ethiopia Central, Addis Ababa, Ethiopia. http://www.csa.gov.et/survey-report/category/347-eth-agss-2016

Food and Agriculture Organization (FAO) (2016). statistical databases FAOSTAT http://faostat3.fao.org/.

Gebremedhin W, Endale G, Kiflu B, Lemaga B (2001). Country profile on Potato production and utilization: Ethiopia. Ethiopian Agricultural Research Organization, Holeta Agricultural Research Centre, Holeta, Ethiopia.

Gebremedhin W, Endale G, Lemaga B (2008). Potato variety development. In Root and tuber crops: The untapped resources, ed. W. Gebremedhin, G. Endale, and B. Lemaga, 15-32. Addis Ababa: Ethiopian Institute of Agricultural Research.

Grant CA, Flaten DN, Tomasiewicz DJ, Sheppard SC (2001). The importance of early season phosphorus nutrition. Canadian Journal of Plant Science 81:211-224.

Henao J, Baanante C (1999). Estimating rates of nutrient depletion in soils of agricultural lands of Africa. International Fertilizer Development Center, Muscle Shoals, AL.

Israel Z, Ali M, Solomon T (2012). Effect of different rates of nitrogen and phosphorus on yield and yield components o Potato (*Solanum tuberosum* L.) at Masha District, southwestern Ethiopia. International Journal of Soil Science 7:146-156.

Jamaati-e-Somarin S, Hokmalipour S, Shiri-e-Janagrad M, Abbasi A (2009). Vegetative growth of potato (*Solanum tuberosum* L.) cultivars under the effects of different level of nitrogen fertilizer. Journal of Biological Science 4(7):807-

814.
Klikocka H (2004). Sulphur fertilization of potato. Fragmenta Agronomica 21(3):80-94. (in Polish).
Klikocka H (2005). The influence of sulphur fertilization on the yield value and infection rate of potato tubers by *Streptomyces scabies* and *Rhizoctonia solani*. Fragmenta Agronomica 4:38-50. (in Polish).
Lalitha BS, Nagaraj KH, Anand TN (2002). Effect of source propagation, level of potassium and sulphur on potato (*Solanum tuberosum* L.). Mysore Journal of Agricultural Sciences 36:148-153.
Lutaladio N, Castaldi L (2009). Potato: The hidden treasure. Journal of Food Composition and Analysis 22(6):491-493.
Mahmoodabad R, Jamaati S, Khayatnezhad M, Gholamin R (2010). Quantitative and qualitative yield of Potato tuber by use of nitrogen fertilizer and plant density. American-Eurasian Journal of Agriculture and Environmental Sciences 9(3):310-318.
Melkamu A, Minwyelet J (2018). Optimum rates of NPS fertilizer application for economically profitable production of potato varieties at Koga Irrigation Scheme, Northwestern, Ethiopia. Cogent Food and Agriculture Cogent Food and Agriculture 4(1): (doi: 10.1080/23311932.2018.1439663).
Mojtaba SY, Mohammadreza HS, Mohammad TD (2013). Effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato (Agria cv.) International Journal of Agriculture and Crop Sciences 5(18):2033-2040.
Mulatu E, Ibrahim O, Bekele E (2005). Improving Potato seed tuber quality and producers livelihoods in Hararghe, Eastern Ethiopia. Journal of New Seeds 7(3):31-56.
Mulubrhan H (2004). The effects of nitrogen, phosphorus and potassium fertilization on the yield and yield components of potato *(Solanum tuberosum* L.), grown on vertisols of Mekelle area Ethiopia. School of Graduate Study, Alemaya University, Ethiopia, MS Thesis.
Munoz F, Mylavarapu RS, Hutchinson CM (2005). Environmentally responsible potato production systems. Journal of Plant Nutrition 28:1287-1309.
Nasreen S, Haq SMI, Hossain MA (2003). Sulphur effects on growth responses and yield of onion. Asian Journal of Plant Sciences 2:897-902.
Rosen CJ, Bierman PM (2008). Potato yield and tuber set as affected by phosphorus fertilization. American Journal of Potato Research 85(2):110-120.
SAS (2008). SAS/STAT. 9.2 computer software. Cary, NC: SAS Institute Inc., USA. https://www.sas.com/en_us/software/stat.html
Sharma DK, Kushwah SS, Nema PK, Rathore SS (2011). Effect of sulphur on yield and quality of Potato (*Solanum tuberosum* L.). International Journal of Agricultural Research 6(2):143-148.
Sharma SP, Sandhu AS, Bhutani RD, Khurana SC (2014). Effects of planting date and fertilizer dose on plant growth attributes and nutrient uptake of potato (*Solanum tuberosum* L.). International Journal of Agricultural Sciences 4(5):196-202.
Sharma VC, Arora BR (1987). Effects of nitrogen, phosphorus, and potassium application on the yield of potato (*Solanum tuberosum* L.) tubers. Journal of Agricultural Sciences 108:321-329.
Singh H, Madhu S, Aakash G, Monika B (2016). Effect of Nitrogen and Sulphur on Growth and Yield Attributes of Potato (*Solanum tuberosum* L.). International Journal of Plant and Soil Science 9(5):1-8.
Sud KC, Sharma RC (2002). Sulphur needs of potato under rainfed conditions in Shimla hills, In: Paul SM, Khurana G, Shekhawat S, Pandey SK, Singh BS (eds.). Potato global research and development, Indian Potato Association, Shimla, India pp. 889-899.
Tamirie H (1989). Increasing agricultural production in Ethiopia through improved soil. Water and crop management practices pp. 243-275. In: Belshaw, D.G.R. (ed.). Towards a food and nutrition strategy for Ethiopia, Proceedings National Workshop on Food Strategies for Ethiopia. Addis Ababa, Ethiopia.
Trehan SP, Dessougi HEL, Claassen N (2005). Potassium efficiency of 10 potato cultivars as related to their capability to use nonexchangeable soil potassium by chemical mobilization. Communications in Soil Science and Plant Analysis 36:1809-1822.
Westermann DT (2005). Nutritional requirements of potatoes. American Journal of Potato Research 82:301-307.
Zelalem A, Takalign T, Nigussie D (2009). Response of potato (*Solanum tuberosum* L.) to different rate of nitrogen and phosphorus fertilization on vertisols at Debre Birhan, in the central highlands of Ethiopia. African Journal of Plant Science 3:16-24.