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Research Article

Response of Potato (*Solanum tuberosum* L.) to Blended NPS and Potassium Fertilizers at Bore, Southern Ethiopia

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ABSTRACT

Potato (*Solanum tuberosum* L.) is one of the most important food security and cash crops in Ethiopia. However, its productivity is generally low. The low yields of the crop could be attributed to a number of factors among which low soil fertility is an important constrain and there is little information on the type and rates of fertilizers to be applied for optimum production of the crop under different agro-ecological conditions of the country. Therefore, an experiment was conducted at Bore Agricultural Research Center, Southern Ethiopia during the 2018 and 2019 cropping season to determine the effect of blended NPS and potassium fertilizer rates on potato, and to assess the cost and benefit of different rates of blended NPS and potassium fertilizers on potato. The treatments consisted of six rates of blended NPS (0, 100, 150, 200, 250 and 300 kg NPS ha^{-1}) and three rates of potassium (0, 100 and 200 kg KCL ha^{-1}) fertilizers, plus100 kg Urea ha^{-1} applied to all plots equally. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a 6*3 factorial arrangement replicated three times. An improved potato variety called Gudanie (CIP-386423-13) was used as a test crop. The two years analysis of the data revealed that the main effects of blended NPS and potassium fertilizers influenced significantly (P<0.01) plant height, number of main stems per hill, average tuber number per hill, marketable and total tuber yields).However, the two fertilizers did not interact to influence all measured parameters of the crop. The highest marketable tuber yields were obtained in response to the application of 200 kg blended NPS ha^{-1} (34.63 t ha^{-1}) and the application of 200 kg ha^{-1} KCL (36.39 t ha^{-1}). On the other hand, the lowest marketable yields of while lowest marketable yield 23.67 t ha^{-1} and 26.01 t ha^{-1}were obtained in response to the application of nil applications of the two fertilizers respectively. The partial budget analysis revealed that application of 200 kg ha^{-1} blended NPS and 200 kg KCL ha^{-1} resulted in the net benefits of 369,654and 389,262ETB ha^{-1}with 2968.69 and 2693.60.00% marginal rate of return respectively. The application of 200 kg KCL ha^{-1} (200 kg KCL + 46 kg N ha^{-1}) or application of 200 kg blended NPS with 46 kg N ha^{-1}(84 kg N ha^{-1} + 76 kg P_2O_5 +14 kg S ha^{-1}) fertilizer rates led to optimum potato tuber production, economic returns and recommended for potato growers in the highland areas of Guji zone.

Key words: Gudanie, Marketable tuber yield and Partial budget analysis.

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family *Solanaceae* and genus *Solanum* (Thompson and Kelly, 1972). It is considered to be the world's fourth important food crop after maize, wheat, and rice because of its high yield potential and nutritive value (Kumar *et al*., 2013; Pandey*et al*., 2014) and the third most important food crop after rice and wheat is being grown and consumed in all over the world (Devaux*et al*., 2014 and FAO, 2015). It is native to South America (Eskin*et al*, 1989). Potato was first cultivated by the Incas of Peru 6000 years ago by Incas in Peru (Ugent *et al*., 1982). Potato is cultivated worldwide in over one hundred countries throughout Africa, Asia, Australia, Europe, and North and South America (USDA, 2014).Potato is one of the widely grown root and tuber crops of the world being a rich source of nutrients for human nutrition. It contains about 79% water,18% starch as a good source of energy, 2% protein and 1% vitamins including vitamin C, minerals including calcium and magnesium and many trace elements (Ahmad *et al*., 2011).The past few decades have seen a dramatic increase in potato production and demand in many developing countries (FAO, 2014).

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Potato has been widely described as global food and nutritional security option particularly for the poor people (Singh and Rana, 2013). Farmers consider potato as a transitional crop that helps them survive the severe and prevailing food shortage that occur every year (Semagn*et al*., 2007). Potatoes are among the most widely-grown crop plants in the world giving good yield under various soil and weather conditions (Lisinska and Leszcynski, 1989). Potatoes generally requires high altitude of about 1200 m above sea level, cool temperatures ranging between 15 and 20°C and high rainfall ranging between 1000 and 1500 mm per year (Gusha, 2014), and optimum soil pH ranges from 5.0 and 6.5 (Havlin *et al*., 1999).

Even though, Ethiopia has suitable environmental condition, the average national yield (14.176 t ha^{-1}) productivity of potato during 2018/19 season (CSA, 2019) is very low as compared with world average yield of 20 tha^{-1} (FAOSTAT, 2019) as well as other top potato producing countries in Africa. On the other hand, the yield potential of the released potato variety in Gudanie ranges between 21 to 29 t ha^{-1} (MoARD, 2009). Moreover, at Bore Agricultural Research Center (2013) an unpublished research progress report clearly indicates that average yield of Gudanie 46.4 t ha^{-1} in the highlands of Guji zone. However, after four years of cultivation, the average yield of Gudanie declined from 46.4 to 29.4 t ha^{-1} in the study area (Dembi*et al*., 2017).The low yields are the result of a number of production constraints mainly involving abiotic and biotic stress factors (Hirut, 2015). Potato, as a high yielding crop, takes up a lot of nutrients from the soil at a given time. The deficiency of any or combinations of high nitrogen (N), phosphorus (P) and potassium (K) can result in retarded growth or complete crop failure under severe cases (Khiari *et al.,* 2001*)*. However, in Ethiopia, N and P fertilizers are used while K application is ignored which causes serious decrease in the status of potassium through depletion in soils of potato growing areas (Pervez, 2013).

Potato requires high amounts of NPK but more K fertilizer for optimum growth, production, and tuber quality (Al-Moshileh and Errebi, 2004), but the ability of this crop to recover P and K is very low. According to Naz*et al*. (2011), response of potato to NPK fertilizers varies depending upon the variety, soil characteristics, and geographical escarpment. The efforts of using N and P containing fertilizers do not satisfy crop nutrient requirements because soil tests through the EthioSIS revealed that Ethiopian soils are deficient in K (EthioSIS, 2013). This is attributed to high soil erosion, removal of nutrients by crops, and continuous cropping with replenishment of nutrients, and inadequate and imbalanced use of organic and inorganic fertilizers (Wassie and Tekalign, 2013). In Ethiopia, low soil fertility is one of the factors limiting the productivity of crops, including potato (Berga*et al*., 1994). This might be caused by land degradation due to up slop cultivation, flooding, soil acidity, low rate of technology adoption by farmers, low inherited soil fertility, limited use of chemical fertilizers is some major negative intervention that slow agricultural productivity in Ethiopia (Tekalign and Hezekeil, 2015).

Lack of adequate nutrient supply, the depletion of organic matter, and soil erosion are the major obstacles to sustained agricultural productivity. Thus, the problem is serious particularly in the high lands of Ethiopia (>1500 meter above sea level) that comprising nearly 44% of the country's total area and 95% of the cultivated area (Krauer, 1988). On the other hand, soil acidity is also now a serious threat to crop production in most highlands of Ethiopia in general and in Guji zone in particular. Even though soil acidity affects the growth crop because acidic soil contains toxic levels of aluminum and manganese and characterized by deficiency of essential plant nutrients such as P, Ca, K, Mg, and Mo (Tisdale*et al*., 1985).

Productivity of the crop is constrained by multidimensional factors such as lack of disease resistant and high yielding varieties with desirable market qualities, limited knowledge of agronomic and crop protection management technologies, and poor post-harvest handling (NigussieDechassa *et al*., 2012). On the other hand, Wassie and Shiferaw (2011) reported that the highest biological and economical yield of potato was obtained from NPK treatment applied at 110:40:100 kg ha^{-1} in the form of urea, TSP and KCl at both HagereSelam and Chencha locations on farmers' fields. Moreover, Melkamu*et al*. (2018) reported that the soils with low phosphorous content, production of Gudanie variety with application 181.60 kg ha^{-1} NPS fertilizer rates produce the highest marketable tuber yield (46.83 t ha^{-1}) which is also recommended for potato production at Koga Irrigation Scheme. In central highlands of Ethiopia, Egata*et al*. (2016) reported that Gudanie produced the highest and economical marketable yield (30.53 t ha^{-1}) at the application of 69 kg ha^{-1} potassium and 110 kg ha^{-1} nitrogen. Furthermore, On the other hand, Mekides*et al*. (2020) reported that the highest potato production was obtained from blended NPS treatment applied 55.5:89.7:16.52 kg ha^{-1} at AbasoKotu, Dessie Zuria District.

According to the soil fertility map made over 150 districts, Ethiopian soil lack about seven nutrients N, P, K, S, Cu, Zn, Band a soil fertility inventory conducted in some woreda from 2012-15 also showed that K is deficient in most of the woreda of the country (EthioSIS, 2013). Application of potassium and sulfur fertilizers in increased nitrogen and phosphorus use efficiency by 80 to 100%; N and P fertilizers saved from blanket recommendation alone could be sufficient to pay the extra cost that farmers incurred due to application of S and K (ATA, 2015). In agreement with this, Wassie*et al*. (2011) also reported supplementation of K increased potato tuber yields by 197% over the standard N-P recommendation alone. Even though, nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer uses on other have favored the emergence of multi nutrient deficiency in Ethiopian soils (Wassie*et al*., 2011).

However, currently in Guji zone no research has so far been conducted in the region to determine the amount of blended NPS and potassium fertilizers for optimum production of potato. Potato growers in the region are recommended to use the blanket rates of only nitrogen and phosphorus fertilizers amounting to 200 kg DAP (92 kg P_2O_5) and 100 kg Urea (82 kg N ha^{-1}) as advised by BoARC(2019). This indicates that the fertilizer recommendation being used to produce the crop in the area is not in accordance with the specific soil and agro-ecological requirements.The recent soil tests through the EthioSIS revealed that Ethiopian soils are deficient in various other nutrients that are not provided by DAP and

Urea (ATA, 2013). On the other hand, the blanket application of DAP and Urea does not give due regard to crop need, soil nutrient dynamics, and agro-ecological factor (Tekalign and Hezekeil, 2015). Therefore, this research was conducted with the following objectives: -

1. To assess the effect of blended NPS and potassium fertilizer rates on potato, and
2. To assess the cost and benefit of different rates of blended NPS and potassium fertilizers on potato

MATERIALS AND METHODS

Description of the Experimental Site: The experiment was carried out during the 2018 and 2019 over two years main cropping season at Bore Agricultural Research Center, Guji Zone of Southern Oromia, which is one of the recently established Research Centers of the Oromia Agricultural Research Institute (OARI). Bore Agricultural Research Center site is located at the distance of about 8 km north of the town of Bore in SongoBericha '*Kebele'* just on the side of the main road to Addis Ababa via Awassa town. Geographically, the experimental site is situated at the latitude of 06°23'55''N and longitude of 38°35'5''E at an altitude of 2728 m above sea level. The soil is clay in texture and strongly acidic with pH value of 5.1 (Arega *et al*., 2018). The traditional farming system of the area is characterized by cultivation of enset as a major crop, maize, potato, head cabbage, barley, wheat and faba bean. As far as fruit and timber crops are concerned, apple and bamboo are the cash crops. Moreover, cattle are an integral part of the farming system (BoARDO, 2015).

Experimental Materials: An improved potato variety called 'Gudanie' which was released by Holetta Agricultural Research Centre in 2006 (MoARD, 2009), was used as a planting material. The variety was selected on the basis of its high yield, wider adaptation and moderate resistance to late blight in highlands of Guji Zone. Blended NPS (19 % N, 38% P_2O_5, and 7% S), and potassium chloride (KCl) were used as sources of nitrogen, phosphorus, sulfur and potash, respectively. Urea (CO ($[NH_2]_2$) (46% N) was used as a source of nitrogen.

Treatments and Experimental Design: The treatments consisted of six rates of blended NPS (0, 100, 150, 200, 250 and 300 kg NPS ha^{-1}) and three rates of potassium (0, 100 and 200 kg KCl ha^{-1}), plus 100 kg Urea ha^{-1} applied to all plots equally. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a 6 x 3 factorial arrangement and replicated three times per treatment. There were 18 treatment combinations, which were assigned to each plot randomly. The total number of plots was 54 and each plot had a gross area of 16.2 m^2 with 3.6 m length and 4.5 m width. Each plot contained six rows of potato plants, with each row accommodating 12 plants with a total population of 72 plants per plot at the spacing of 0.75 m and 0.30 m between rows and plants, respectively. The spacing between plots and adjacent blocks was 1 m and 1.5 m, respectively. For data estimation, tubers were harvested from middle rows, leaving the plants growing in the two border rows as well as those growing at both ends of each row to avoid edge effect (EARO, 2004).

Experimental Procedure and Crop Management: The blended NPS, urea and potash (KCl) fertilizers at the specified rates were applied by banding the granules of the two fertilizers at the depth of 5 cm below and around the seed tuber at planting. All blended NPS and potash were applied at planting. The urea dose was applied in three splits [¼at planting, ½ at mid-stage of the plant (at about 40 days after planting), and ¼ at the initiation of tubers (at the start of flowering)]. All urea applications were made at time when the soil moisture is not excessively high to avoid leaching of N.

All the other cultural practices were followed as per the recommendation for raising a successful crop. The first, second and third earthing-up was done 15, 30, and 45 days after planting to prevent exposure of the tubers to direct sunlight, promote tuber bulking and ease of harvesting. Weeds were controlled by hoeing and haulms were also mowed two weeks before harvesting at physiological maturity to toughen the periderm for reducing skinning and bruising during harvesting and post-harvest handling. Ridomil Gold was sprayed two times at the rate of 2.5 kg ha^{-1} at the interval of 7 days using 400 to 500 liters of water ha^{-1} to control late blight disease.

Soil Sampling and Analysis: The composite soil samples was collected by using Auger (Soil sampler) from 0-30 cm depth based on the procedure outlined by Taye Bekele (2000) and using the zigzag method (Carter and Gregorich, 2008).The surface soil samples collected from the experimental field was air dried and grinded and allowed to pass through 2 mm sieve and for further analysis for total nitrogen and organic carbon allowed to pass through 0.5 mm sieve (FAO, 2008). Pre(before) planting and post (immediately after harvesting of crop)soil samples were analyzed for particle size distribution (soil texture), soil pH, Cation exchange capacity (CEC) (Meq/100g soil), organic carbon (%), available potassium (ppm), phosphorus (ppm), and available sulfur(ppm), boron(ppm), total nitrogen (%), exchangeable magnesium, sodium, and calcium (Cmol (+) kg^{-1}) at Horti coop Ethiopia soil and water analysis laboratory.

The soilreaction (pH) was measured according to FAO (2008) using 1:2.5 (weight/volume) soil sample to H_2O ratio using a glass electrode attached to a digital pH meter. Soil texture was determined by using Bouyoucos Hydrometer Method (Bouyoucos, 1962) following the textural triangle of (USDA, 1987) system as described by Rowell (1994). Soil organic carbon content was determined by using the Walkley and Black method (Walkley and Black, 1934) and soil organic matter content was calculated by multiplying the OC% by a factor 1.724. Total nitrogen of the soil was determined by Kjeldhal Method (Jackson, 1958). Available B will be determined using hot water method (Berger and Truog, 1939). Available S was determined by monocalcium phosphate extraction method or turbidimetric estimation (Johnson and Fixen, 1990) and available phosphorus was determined by Bray II methods (Bray and Kurtz, 1945). Cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc (Chapman, 1965).Exchangeable bases (Aluminum, potassium, magnesium, sodium, and calcium) were determined by Melich-3 methods (Mehlich, 1984).

Data Collection

Phenology of potato

Days to 50% flowering: It was determined by counting the number of days from emergence to the time when 50% of the plants in each plot started to flower through visual observation.

Days to 90% physiological maturity: It wasdetermined by counting the number of days from emergenceto the days when more than 90% of the plants in a plot attained physiological maturity, *i.e.* when plants to reach the stage of growth when 90% of the leaves/ halums started to senesce.

Growth of potato crop

Plant height (cm): refers to the height from the base to the apex of the plant. It was determined by measuring the height of 12 randomly taken plants per plot using a meter from the central four rows at flowering (or tuber initiation).

Average number of main stems per hill: was determined by counting the stems that originated from the tuber from 12 plants randomly taken per hills, and taking the average.

Yield components of potato

Average tuber number perhill: This was recorded as the actual number of tubers to be collected from 12 matured plants at harvest.

Average tuber weight (g): was determined at harvest by dividing the weight of all tubers obtained from randomly taken 20 tubers per plot and divided by 20.

Tuber yields

Marketable tuber yield (t ha^{-1}): the weight of tubers which are free from diseases, insect pests, and greater than or equal to 25 g in weight were recorded from 40 plants per hill.

Unmarketable tuber yield (t ha^{-1}): the weight of tubers that are diseased and/or rotting ones and small-sized (less than 25 g in weight) were recorded.

Total tuber yield (t ha^{-1}): the total tuber yield was obtained by adding marketable and unmarketable tuber yields.

Data Analysis: The data were subjected to analysis of variance (ANOVA) using Gen-Stat release 15th Edition software (Gen-Stat, 2012). The result interpretations were made following the procedure of Gomez and Gomez (1984) and means of significant treatment effects were separated using the Fishers' protected Least Significant Difference (LSD) test at 5% probability level of significance.

Partial Budget Analysis: The economic analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on ha basis in Birr. The concepts used in the partial budget analysis were the mean marketable tuber yield of each treatment, the gross benefit (GB) ha^{-1} (the mean marketable tuber yield for each treatment) and the field price of fertilizers (the costs of blended NPS and KCL and the application costs).

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

Adjusted yield (AjY): AjYwas the average yield adjusted downward by a 10% to reflect the difference between experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by 10% less than that of the research results (CIMMYT, 1988).

Adjustable marketable tuber yield = Average yield - (Average yield -0.1)

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

Gross field benefit (GFB) = Adjustable marketable tuber yield*field/farm gate price for potato.

Total variable cost (TVC): Total cost was the cost of fertilizers and application cost of fertilizers as differ dosage for the experiment. The costs of other inputs and production practices such as labor cost, land preparation, planting, Earthingup, weeding, top killing, and harvesting were considered the same or are insignificant among treatments.

Net Income (NI) or Net Benefit (NB): - was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the total revenue (TR).

NB = TR – TVC

Marginal rate return (MRR): was the measure of increasing in return by increasing input.

$$\text{MRR} = \frac{\text{Change of Net Benefit } (\Delta\text{NB})}{\text{Change of Total Variable Cost } (\Delta\text{TVC})}$$

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

$$\text{MRR\%} = \frac{\text{Change of Net Benefit } (\Delta\text{NB})}{\text{Change of Total Varaible Cost } (\Delta\text{TVC})} \times 100$$

Dominance Analysis (identification and elimination of inferior treatments): is also used to eliminatethose treatments which involve higher cost but do not generate higher benefits. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefit) is dominated treatment (marked as "D"). Identification of a candidate recommendation was from among the non-dominated treatments. That was the treatment which gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers (>1 or 100%).

RESULTS AND DISCUSSION

Physico-Chemical Properties of the Experimental Soil: The laboratory results of the selected physico-chemical properties of the soil sample taken before planting are presented in (Table 1 &2). The results indicate that the soil has 33, 27 and 40% sand, silt and clay, respectively, and could be categorized as clay soil on the basis of USDA (1987) textural soil classification system. According to Murphy (2007), the experimental soil has medium CEC (24. 86 Meq/100g soil). The rating made by FAO (2006)

Table 1: Physical and chemical properties of the experimental site before-planting at Bore on-station during 2018 main cropping season

Properties	Result	Rating	References
1. Physical properties (%)			-
Sand (33%), Silt (27%), and Clay (40%)			-
Textural Class	Clay		(USDA,1987)
2. Chemical Properties			-
pH (1: 2.5 H_2O)	5.1	Strongly Acidic	(EthioSIS, 2014)
Organic Matter /OM/ (%)	5.17	Medium	(EthioSIS, 2014)
Organic Carbon /OC/ (%)	3.0	Medium	Tekalign (1991)
CEC (meq/100 g soil)	24.86	Medium	Murphy (2007)
Total Nitrogen /TN/ (%)	0.25	Medium	(EthioSIS, 2014)
Available Phosphorus /P/ (ppm)	12.10	Medium	Cottenie (1980)
Available Potassium /K/ (ppm)	60.50	Very Low	(EthioSIS, 2014)
Available Sulfur /S/ (ppm)	2.50	Very Low	(EthioSIS, 2014)
Available Boron /B/ (ppm)	0.84	Medium	(EthioSIS, 2014)
3.Exchangeable Bases (Cmol(+)kg^{-1})			
Exchangeable Na^+	0.19	Low	(FAO, 2006)
Exchangeable K^+	0.16	Very low	(FAO, 2006)
Exchangeable Ca^{++}	8.87	Medium	(FAO, 2006)
Exchangeable Mg^{++}	1.45	Medium	(FAO, 2006)

Table 2: Physical and chemical properties of the experimental site before-planting at Bore on-station during 2019 main cropping season

Properties	Result	Rating	References
1. Physical properties (%)			-
Sand (33%), Silt (27%), and Clay (40%)			-
Textural Class	Clay		(USDA,1987)
2. Chemical Properties			-
pH (1: 2.5 H_2O)	4.66	Strongly Acidic	(EthioSIS, 2014)
Organic Matter /OM/ (%)	4.72	Medium	(EthioSIS, 2014)
Organic Carbon /OC/ (%)	2.74	Medium	Tekalign (1991)
Total Nitrogen /TN/ (%)	0.29	Medium	(EthioSIS, 2014)
Available Phosphorus /P/ (ppm)	8.39	Very low	Cottenie (1980)
Available Potassium /K/ (ppm)	212.55	Medium	(EthioSIS, 2014)
Available Sulfur /S/ (ppm)	20.14	Very Low	(EthioSIS, 2014)
Available Boron /B/ (ppm)	0.54	Low	(EthioSIS, 2014)
CEC (meq/100 g soil)	23.91	Medium	Murphy (2007)
Exchangable Acidity (meq/100 g soil)	0.21	-	-
Exchangable H^+(meq/100 g soil)	0.21	-	-
3.Exchangeable Bases (Cmol(+)kg^{-1})			
Exchangeable Na^+	0.075	Very low	(FAO, 2006)
Exchangeable K^+	0.55	Medium	(FAO, 2006)
Exchangeable Ca^{++}	7.43	Medium	(FAO, 2006)
Exchangeable Mg^{++}	1.2	Medium	(FAO, 2006)

indicate that the contents of exchangeable Na is low (0.19 Cmol (+) kg^{-1}), exchangeable potassium is very low (0.16 Cmol (+) kg^{-1}), exchangeable Ca is medium (8.87 Cmol (+) kg^{-1}) and exchangeable Mg is medium (1.45 Cmol (+) kg^{-1})). According to the rating of Tekalign (1991), the organic carbon (OC) content (3.0%) could be categorized as medium.

Furthermore, according to Karltun*et al*. (2013) andEthioSIS (2014) the soil of the experimental site is strongly acidic in reaction (pH of 5.1), medium in total N (0.25%), very low in available potassium (60.50 ppm) and very low in available S (2.50ppm). The results of the analysis also indicated that the soil has a medium content of available phosphorus (12.10 ppm) in 2018 cropping season according to the rating of Cottenie (1980). The low potassium content may be attributed to the nature of the clay which is kaolinite, having poor retention capacity of potassium ions and hence high susceptibility to leaching of the cation (Mengel and Kirkby, 2001) due to heavy rainfall in the study area. At increased soil acidity (low pH), phosphorus is fixed to surfaces of Fe and Al oxides and hydrous oxide, which are not readily available to plants (Sikora*et al*., 1991).

Potatoes can grow under a wide range of soil pH varying from neutral to alkaline reaction (Fageria, 2011). However, the optimum soil pH for potato production ranges from 5.0 – 6.5 (Havlin *et al*., 1999), which varies from very strongly acidic to slightly acidic reaction (Hazelton and Murphy, 2007). Therefore, the pH of the experimental soil is suitable for potato production.

However, the low content of available potassium and sulfur as well as the medium contents of available phosphorus, organic carbon, and total nitrogen indicate that application of mineral and/organic fertilizers containing these nutrients is important for optimum production of the crops in the study area.

Physico-Chemical Properties of the Experimental Soil after Potato Crop Harvest: The post-harvest physiochemical properties of soil as affected by blended NPS and potassium at different fertilizer rates are presented in Table 3. Post-harvest analysis of soil revealed an increasing organic matter (5.92, 5.87 and 5.77%) at the rates of 100,200 kg blended NPS with combined application rates of 100, and 200 kg potassium ha^{-1} respectively. The post-harvest soil analysis result indicates

Table 3: Physical and chemical properties of the experimental site post harvesting at Bore on-station during 2019 main cropping season

Treatments	PH.H20 0-14	Av. P Mg/kg	Av. S Mg/kg	Avail. K Mg/kg	TN %	OM %	CEC Meq/100g s	Textural class
100NPS +100KCL	4.48	6.57	10.92	164.30	0.32	5.92	22.36	Clay
300NPS+100KCL	4.39	6.89	15.64	190.80	0.32	5.29	26.96	
300NPS +0KCL	4.41	5.30	14.20	201.40	0.30	5.30	19.83	
100NPS+0KCL	4.52	6.53	11.45	171.20	0.20	5.56	27.99	
250NPS+100KCL	4.62	7.42	13.25	201.40	0.31	5.33	29.43	
150NPS +0KCL	4.64	8.35	14.34	165.85	0.31	5.50	26.21	
250NPS+0KCL	4.55	5.46	14.82	144.45	0.31	5.41	27.11	
200NPS + 100KCL	4.52	6.47	13.73	132.50	0.31	5.87	33.89	
300NPS+200KCL	4.82	7.28	16.75	171.20	0.30	5.58	27.64	
200NPS +0KCL	4.48	7.24	14.96	129.60	0.32	5.50	23.43	
0NPS+0KCL	4.44	5.99	12.89	176.55	0.31	5.34	26.04	
0NPS+200KCL	4.85	6.96	17.71	224.70	0.33	5.48	24.37	
150NPS +100KCL	4.39	5.46	10.54	133.75	0.32	5.14	28.17	
150NPS +200KCL	4.50	5.97	9.22	164.80	0.30	5.48	29.22	
100NPS+200KCL	4.48	6.63	15.78	112.35	0.31	5.63	28.74	
0NPS +100KCL	4.52	5.19	8.66	169.60	0.31	5.56	21.94	
200NPS+200KCL	4.46	7.84	14.20	190.80	0.32	5.77	27.69	
250NPS+0KCL	4.34	8.37	17.97	169.60	0.32	5.24	24.79	

Table 4: Effect of blended NPS and potassium fertilizer rates on phenology of Gudanie potato variety at Bore during 2018, 2019, and pooled of two years.

Blended NPS (kg ha^{-1})	Phenology					
	2018	2019	Pooled mean	2018	2019	Pooled mean of 90% DM
	50% DF	50% DF	of 50% DF	90% DM	90% DM	
0	50.67^{c}	56.67c	52.67c	112.2^{d}	98.2b	105.2c
100	56.00^{b}	57.89abc	56.94b	114.2^{c}	99.9b	107.1bc
150	56.22^{b}	55.89bc	56.06b	114^{cd}	99.4b	106.7bc
200	59.67^{a}	62.22a	60.94a	117.3^{b}	101b	109.2abc
250	60.56^{a}	61.44ab	61a	120.2^{a}	104.9a	112.6ab1
300	60.78^{a}	62.11a	61.44a	120.4^{a}	107a	113.7a
LSD (5%)	2	9.36	2.86	1.86	4.63	5.61
KCl rates (kg ha^{-1})						
0	57.17	57	57.08b	114.1^{c}	100.2b	107.1a
100	57.5	61	59.25a	116.7^{b}	101.8ab	109.2a
200	57.28	59.11	58.19ab	118.4^{a}	103.3a	110.9a
LSD (5%)	NS	NS	2.03	1.32	4.63	3.97
CV (%)	3.7	9.6	7.4	1.7	2.7	7.8

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance;50% DF= days to fifty percent flowering, 90% DM= days to ninety percent physiological maturity, CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Table 5: Effect of blended NPS and potassium fertilizer rates on Growth of Gudanie potato variety at Bore during 2018, 2019, and pooled of two years.

Blended NPS (kg ha^{-1})	Growth Parameters					
	2018	2019	Pooled mean	2018	2019	Pooled mean
	PH (cm)	PH (cm)	of PH (cm)	SN(no.)	SN(no.)	of SN(no.)
0	53.14^{e}	50.05a	51.59c	5.85^{c}	3.41c	4.57b
100	61.29^{d}	55.72ab	58.5b	6.14^{bc}	3.57bc	4.97ab
150	63.3^{cd}	62.54a	62.92ab	6.42^{abc}	3.53bc	5.03ab
200	65.46^{bc}	62.05a	63.76a	6.8^{ab}	4.16a	5.64ab
250	67.79^{ab}	61.62a	64.7a	6.99^{a}	3.9ab	5.84a
300	69.55^{a}	62.28a	65.92a	7.07^{a}	4.33a	6.14a
LSD (5%)	3.95	11.64	4.56	0.84	0.72	1.07
KCl rates (kg ha^{-1})						
0	56.43^{b}	52.25b	54.34c	6.06^{b}	3.62b	4.88b
100	65.8^{a}	56.77b	61.29b	6.43^{b}	3.64b	5.12b
200	67.78^{a}	68.1a	68.07a	7.15^{a}	4.18a	6.11a
LSD (5%)	1.98	11.64	3.32	1.46	0.72	0.76
CV (%)	6.5	11.9	11.3	13.4	11.3	30.1

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; PH (cm)= plant height in centimeter, Sn= Stem Number,CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

that experimental site is clay.The nil received plots, 300,150 kg blended NPS with combined application of 200 kg and nil received plots of potassium fertilizer some extent increase strongly acidic reaction (pH of 4.85, 4.82, and 4.64) respectively. So, this pH results were in agreement with the suggestion of Havlin *et al*. (1999) who reported that the optimum soil pH for potato production ranges from 5.0 – 6.5. The post-harvest soil analyses indicate that, the

Table 6: Effect of blended NPS and potassium fertilizer rates on average tuber numbers andaverage tuber weight of Gudanie potato variety at Bore during 2018, 2019, and pooled of two years.

Blended NPS (kg ha^{-1})	Yield component parameters					
	2018 TN(no.)	2019 TN(no.)	Pooled mean of TN(no.)	2018 TW (g)	2019 TW (g)	Pooled mean of TW (g)
0	10.10^{c}	6.63c	7.98b	60.44^{b}	81.59	71.02b
100	12.39^{ab}	8.25ab	10.32a	62.45^{b}	91.18	76.82ab
150	12.62^{ab}	7.61bc	10.11a	62.06^{b}	100.06	81.06ab
200	11.68^{b}	8.97a	10.32a	77.71^{a}	100.03	88.87a
250	12.29^{ab}	8.49ab	10.39a	65.07^{b}	101.9	83.48ab
300	13.43^{a}	8.1ab	10.77a	67.04^{b}	98.44	82.7ab
LSD (5%)	1.32	1.89	1.79	9.04	NS	15.54
KCl rates (kg ha^{-1})						
0	10.78^{c}	7.66	9.14b	63.68	112.71a	72.19b
100	12.03^{b}	8.11	9.95ab	66.04	93.2b	79.62ab
200	13.45^{a}	8.26	10.85ab	67.65	80.69b	90.18a
LSD (5%)	0.93	NS	1.27	NS	31.95	10.99
CV (%)	11.4	14.2	27.1	14.3	20.2	29.10

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; TN(no.)= Tuber numbers per hill, TW (g) = Tuber weight in gram, CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Table 7: Effect of blended NPS and potassium fertilizer rates on tuber yields of Gudanie potato variety at Bore during 2018, 2019, and pooled of two years.

Blended NPS (kg ha^{-1})	Tuber yield parameters								
	2018 Myld (t ha^{-1})	2019 Myld (t ha^{-1})	Pooled mean of Myld (t ha^{-1})	2018 UM yld (t ha^{-1})	2019 UM yld (t ha^{-1})	Pooled mean of UM yld (t ha^{-1})	2018 Tyld (t ha^{-1})	2019 Tyld (t ha^{-1})	Pooled mean of Tyld (t ha^{-1})
0	24.96^{d}	22.3ab	23.67c	2.01^{b}	1.99	2.01b	26.97^{d}	24.38b	25.68d
100	31.31^{c}	30.41a	30.86b	3.043^{ab}	2.09	2.86a	34.35^{c}	33.09a	33.72c
150	31.71^{c}	31.36a	31.54ab	2.71^{ab}	2.77	2.40ab	34.42^{c}	33.46a	33.94bc
200	36.41^{a}	32.84a	34.63a	3.50^{a}	2.77	3.14a	39.91^{a}	35.61a	37.76a
250	34.26^{bc}	35.06a	33.58ab	3.19^{a}	2.6	2.89a	37.45^{bc}	37.66a	36.47abc
300	36.06^{ab}	32.34a	34.20ab	3.24^{a}	2.77	2.96a	39.30^{b}	35.06a	37.16ab
LSD (5%)	3.44	8.21	3.10	0.93	NS	0.68	3.54	7.96	3.09
KCl rates(kg ha^{-1})									
0	27.51^{c}	24.5c	26.01c	2.6	2.9a	2.80	30.11^{c}	27.5c	28.81c
100	32.2^{b}	30.84b	31.54b	2.88	2.26b	2.57	35.08^{b}	33.13b	34.10b
200	36.55^{a}	36.83a	36.39a	3.37	2.15b	2.76	39.92^{a}	38.98a	39.45a
LSD (5%)	2.43	8.21	2.19	0.66	1.44	NS	2.5	7.96	2.19
CV (%)	11.2	16.1	14.9	NS	35.1	38.1	10.2	14.5	13.7

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; Myld (t ha^{-1})= Marketable tuber tone per hectare, UM yld(t ha^{-1})= Unmarketable tuber yield ton per hectare, Tyld (t ha^{-1})=Total tuber yield ton per hectare, CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

experimental soil has medium to high CEC (Meq/100g soil) by the application of blended NPS and potassium application of blended NPS and potassium at different fertilizer ratesMurphy (2007).

According to EthioSIS (2014) the post-harvest soil analysis indicates that very low in available P (Mg/kg), available potassium ranged very low to optimum, available S(Mg/kg) ranged optimum to high, total nitrogen(%) ranged optimum to high by the application ofblended NPS and potassium atdifferent fertilizer rates. In particular, application of large quantities of phosphorus, potassium fertilizers, which is important for increasing potato production at the experimental site and it also, seems an important step towards enhancing potato yield in the study area. Therefore, this experimental site indicates that, which includes integrated application of P and K, and FYM is acceptable for changing nutrient availability and lowering acidity/ increasing pH value of the experimental site.3.2. Phenology of Potato.

The results from the analysis of variance indicated that application of the blended NPS fertilizer had a highly significant ($P < 0.01$) effect on days to 50% flowering and 90% physiological maturity. The interaction effect of blended NPS and potassium fertilizers on days to 50% flowering and 90% physiological maturity was non-significant(Appendix Table 1). Increasing blended NPS application from 0 to 300 kg ha^{-1} delayed 50% flowering (tuber initiation) by 14.27%. Increasing the blended NPS supply beyond to 200 and 300 kg ha^{-1} delayed 50% flowering of the plants by about 8.14% as comparedtoplantsgrowninthecontroltreatment(Table4).However, plants grown at the application of 200 and 300 kg ha^{-1} blended NPS fertilizer had statistically similar days to 50% flowering. Thus, compared to the plants in plots that did not receive the fertilizer, plots that received the blended NPS at the maximum rate of 300 kg ha^{-1} required about 8.5 days (about 7.48%) to attain 90% physiological maturity. Increasing the rate of potassium application beyond 0 kg KCL ha^{-1} did not affect days to 50% flowering and days to 90% physiological maturity.

The delayed maturity of plants in response to the application of the blended NPS fertilizer at higher rates

Table 8: Partial budget and marginal rate of return analysis for response of Gudanie potato variety to the application of blended NPS and potassium fertilizer rates at Bore during 2018 and 2019 cropping season

Treatments Blended NPS ($kgha^{-1}$)	Unadjusted Myld($kgha^{-1}$)	Adjusted Myld($kgha^{-1}$)	Total VariableCost(ETB)	Gross Return(ETB)	Net Benefit(ETB)	MRR (%)
0	23670	21303	0	255636	255636	-
100	30860	27774	2175	333288	331113	3470.21
150	31540	28386	3262.5	340632	337369.5	575.31
200	34630	31167	4350	374004	369654	2968.69
250	33580	30222	5437.5	362664	357226.5	D
300	34200	30780	6525	369360	362835	515.72
Potassium rates (kg ha^{-1})						
0	26010	23409	0	280908	280908	-
100	31540	28386	1875	340632	338757	3085.28
200	36390	32751	3750	393012	389262	2693.60

Where, blended NPS cost = Birr 18 $kg^{-1}$of blended NPS, K_2Ocost = Birr 15 kg^{-1}, blended NPS and K_2O fertilizers application cost=Birr 3.75 $kg^{-1}$of blended NPS and K_2O, Application cost of blended NPS and K_2O fertilizers 5 persons 100 kg ha^{-1},each 75 ETB day^{-1}, Field price of potato during harvesting = Birr 12 birr kg^{-1}, Myld =Marketable tuber yield, MRR (%) = Marginal rate of return and D= Dominated treatment.

Appendix Table 1:.Mean squares of ANOVA for potato parameters response of potato to blended NPS and Potassium fertilizer rates at Bore, Southern Ethiopia in 2018 and 2019 growing season

Variable/Sources	Block	Blended NPS	KCl	Blended NPS x KCl	Error
Degrees of freedom	2	5	2	10	34
Days to 50% flowering	14.05	225.68**	42.26^{NS}	14.59ns	18.69
Days to 90% maturity	17.15	209.44**	125.29Ns	14.06ns	71.64
Plant height(cm)	153.03	516.88**	1697.54**	39.75ns	47.47
Number of main stem hill^{-1}	6.73	6.46**	15.23**	2.80ns	2.6
Average tuber number hill^{-1}	17.05	18.14**	26.03**	2.39ns	7.31
Average tuber weight (g/tuber)	1036.5	675.3Ns	2943.1^{**}	133.8ns	550.50
Marketable tuber yield(t ha^{-1})	5.11	3.56*	2056.423^{NS}	$1456ns^{NS}$	21.90
Unmarketable tuber yield(t ha^{-1})	4.39	3.23**	0.55ns	0.74ns	1.07
Total tuber yield(t ha^{-1})	0.10	358.20**	1020.26**	16.05ns	21.77

Where, **= highly significant at P≤0.01 probability level, * = significant at P≤0.05 probability level and Ns = non-significant at P>0.05 probability level.

might be due to the effect of nitrogen contained in the fertilizer which may have stimulated plant growth, enlarged leaves and tubers but delayed flowering and maturity. This suggestion is in agreement with that of Tantowijoyo and Van de Fliert (2006) that the application of nitrogen fertilizer at higher rates enhances vegetative growth by helping the plant to absorb sunlight and produce carbohydrates but delayed the production of reproductive part and thereby maturity.

In agreement with the results of this study, Zelalem*et al.* (2009) and Biruk*et al*. (2015) who reported that application of N and P fertilizers delayed flowering and prolonged days required attaining physiological maturity of potato. This result is consistent also with that of Habtam*et al.* (2012) who reported that increasing potassium fertilizer rate prolonged the days required to attain 50% flowering in potato. In contrast with the results of this study, Minwyelet*et al*. (2017) and Getachew*et al.* (2016) reported that there were no significant differences required for days to flowering in potato due to the application of blended fertilizer treatments respectively.

Growth of Potato Crop: The plant height and main stem number per hill of Gudanie potato variety were highly significantly (P<0.01) influenced by application of the blended NPS as well as the potassium fertilizers but not by the interaction of the two factors (Appendix Table 1).

Plant height: Increasing the rates of both fertilizers increased plant height. Increasing the rate of the blended NPS from nil to 300 kg NPS ha^{-1} increased the height of the potato plants significantly by about 27.78%. However, non-significant increment in potato plant heights was observed in response to increasing the rate of the NPS from 200 to 300 kg ha^{-1} and also 250 to 300. This indicates that application of NPS beyond 200 kg NPS ha^{-1} was not necessary for enhancing the height of the crop plant. On the other hand, increasing application of the potassium fertilizer from nil to 200 kg KCl ha^{-1} increased the height of the plants by about 25.27%. Increment in plant height was observed in response to the rate of fertilizer nill to 200 kg KCl ha^{-1} (Table 5). This shows that application of beyond 100 kg KCL ha^{-1} is important to obtain the optimum height of the plant.

In agreement with this result, Minwyelet*et al.* (2017) and Melkamu*et al.* (2018) reported that the tallest potato plants were observed in response to increasing the rate of NPS application from 272 and 281.75 kg ha^{-1} NPS fertilizer rates. This result is in agreement with the findings of Asmaa and Hafez (2010), Habtam*et al*. (2012) and Egata*et al.* (2016) reported that application of higher rates of potassium resulted in higher plant height of potato.

The increased plant height in response to the application of the fertilizersmay be attributed the influence of the nutrients contained on enhancing plant growth owing to their contribution to enhanced cell division, elongation and vegetative growth of plants (Marschner, 1995).

Main stem number per hill: Increasing the rates of the two fertilizers, significantly increased stem number per plant.

However, increasing the rate of NPS application increased stem number per plant from nil only up to 100 kg NPS ha^{-1}. Thus, the highest stem number of per plant was attained already at the rate of 300 kg NPS ha^{-1}. However, increasing the rate of potassium application from nil to 100 kg KCl ha^{-1} did not increase the number of stems produced per plant. However, increasing the rate of the fertilizer to 200 kg KCl ha^{-1} increased the number of stems significantly by 25.2% (Table 5).

This result is consistent with that of Minwyelet*et al*. (2017) who reported that increasing application of NPS fertilizer rates increased the main stem number of potatoes. Similarly, the result is in agreement with the findings of Khandakhar*et al.* (2004) who reported that stem number per plant increased significantly with increasing the level of lime and potassium application. This result also conforms to that of Niguse(2016) who reported that application of P and K fertilizers significantly increased stem number per hill. In contrast with the findings of Habtam*et al. (*2012) who reported that stem number per plant of potato was not affected by potassium application at Assosa, the soil of which has also low content of available potassium as the soil of this experimental site.

Yield Components of Potato: The average tuber numbers per hill were highly significantly (P<0.01) influenced by the application of blended NPS and potassium fertilizers on Gudanie potato variety. Furthermore, application of the potassium fertilizer had a highly significant effect on average tuber weight but not blended NPS fertilizer as well as the interaction of the two factors (Appendix Table 1).

Average tuber numbers: Increasing the rate of the blended NPS application from nil to 100 kg ha^{-1} significantly increased the average tuber number per hill by about 29.32%. However, increasing the rate of the NPS fertilizer beyond 100 kg ha^{-1} did not affect this parameter (Table 6). This shows that increasing the rate of NPS did not vigorously affect average tuber numbers of the plant. However, increasing the rate of potassium application from nil to 100, and 200 kg KCl ha^{-1} increased tuber numbers per hill significantly and linearly, by about 18.71% (Table 6). This shows that potassium application had a more vigorous effect tuber production than application of the blended NPS fertilizer.

These results are consistent with that of Daniel *et al*. (2016) who reported that number of tubers per potato plant increased in response to increasing the rate of potassium application. Similarly, Habtam *et al*. (2012) and Niguse (2016) reported that P and K fertilizer application significantly increased the number of tubers produced per plant

Due to the significant role of potassium on photosynthesis, favors high energy status which helps the crop for timely and appropriate nutrients translocation and water absorption by roots. In agreement with this, high rates of photosynthesis were found to produce a greater number of tubers per plant (Bergmann, 1992).

Average tuber weight: Increasing the rate of the blended NPS application from nil to 200 kg ha^{-1} significantly increased the average tuber number per hill by about 25.13%. The highest average tuber weight (88.87g) was observed at blended NPS 200 kg ha^{-1} while the lowest (71.02g) was at the unfertilized plots. Average tuber weight was affected by the application of potassium fertilizer rate (Table 6).

Nitrogen application to potatoes before tuber initiation increases the number of tubers per plant and mean fresh tuber weight (Kanzikwera *et al*., 2001). The increase in average tuber weight of tubers in response to the increased supply of fertilizer nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthates which may have induced formation of bigger tubers thereby resulting in higher yields (Patricia and Bansal, 1999). Tuber weight or size is not affected by potassium application but by phosphorus application.

This is not consistent with the finding of Zelalem (2009) who reported that the average tuber weight progressively increased with increasing N rate up to 138 kg/ha and tended to decrease at the highest rate of 207 kg/ha. The results of the present study are also not lined with the findings of various researchers (Melkamu *et al*., 2018; Minwyelet *et al*., 2017) who reported that the application of NPS fertilizer increased mean tuber weights of potato.In line with this study result of Israel *et al*. (2012) and Biruk *et al.* (2015) stated that the application of nitrogen and phosphorus not influenced average tuber weight of potato. In consistent with the findings of Niguse *et al*. (2016) who reported that the application of K fertilizer affected average tuber weight, as the K fertilizer rate in creased the average tuber weight increase.

Tuber Yields: The application of blended NPS and KCL fertilizers had significant (P<0.01) effect on tuber yields (marketable and total tuber yield) of Gudanie potato variety. Furthermore, application of the potassium fertilizer had no significant effect on unmarketable tuber yield. But the two fertilizers did not interact to influence these parameters (Appendix Table 1).

Marketable tuber yield: Increasing the rate of blended NPS fertilizer from nil to 200 kg ha^{-1} increased marketable tuber yield significantly. This increment amounted to about 46.3%. However, increasing the rate of the fertilizer beyond 200 kg ha^{-1} did not increase the marketable yield. However, further increasing the rate of the fertilizer beyond 200 kg ha^{-1} increased the marketable tuber yield of the crop by about 46.3%, beyond which no increment was recorded (Table 7). In this case, the highest or optimum marketable tuber yield was obtained already at the rate of 200 kg NPS ha^{-1}.

Increasing the rate of potassium fertilizer from nil to 200 kg KCl ha^{-1} increased the marketable tuber yield by about 39.91%. Thus, the response of marketable tuber yield to the application of potassium fertilizer was much more vigorous and continuous at each rate of the fertilizer than the response observed for application of the blended NPS fertilizer (Table 7). The highest marketable tuber yield (36.39 t/ha) was obtained at the highest rate, which is of 200 kg KCl ha^{-1}.This lined with (Panique *et al*., 1997) who reported that Potato has a high K demand.

The maximum marketable tuber yield of the crop was obtained in response to the application of 200 kg KCL ha^{-1} (Table 7) which indicates that potassium is an important limitation to the productivity of the crop in the area. On the hand, reduction in yield due to high rate of N application could be explained by a phenomenon that extra nitrogen application often stimulates shoot growth at the expense of tuber initiation and bulking (Sommerfeld and Knutson, 1965).

Consistent with the results of this study, Habtam*et al.* (2012) also reported that the amount of mineral potassium fertilizer that optimized marketable and total tuber yields of potato was 200 kg KCL ha^{-1} in Assosa, which has also low availability of the mineral nutrient. Similarly, Bansal*et al.* (2011) reported that application of 100 kg KCl ha^{-1} as MOP significantly increased marketable yield of potato. This result is consistent also with those of Minwyelet*et al.* (2017) and Melkamu*et al.* (2018) who reported that the application of NPS fertilizer at the rate of 272 kg ha^{-1} resulted in the production of the highest marketable tuber yield (47.02 t ha^{-1}) of potato. The result is also in line with that of Getachew*et al.* (2016) who reported that the maximum marketable yield was obtained in response to the application of 100 kg ha^{-1} blended NPKSZ and the lowest recorded from unfertilized plots. Consistent with the results of this study, Nikardi (2009) reported that application of 200 kg, KCl ha^{-1} resulted in the production ofthe highest potato tuber yield.

Unmarketable tuber yield: Increasing the rate of blended NPS fertilizer from nil to 100 kg ha^{-1} significantly increased the unmarketable tuber yield by about 42.29%. However, the unmarketable yield was not affected by the rates of the fertilizers applied above this rate. On the other hand, application of the potassium fertilizer did not affect the unmarketable tuber yield of the crop (Table 7).

In general, the response of unmarketable tuber yield of the crop to both fertilizers was not vigorous. This result is consistent with the suggestion of (Berga*et al.* (1994) that unmarketable tuber yield might be controlled more importantly by manipulating other factors such disease incidence, harvesting practice, etc. rather than mineral nutrition.

In accordance with this study result, Zelalem*et al.* (2009) and Mulubrhan (2004) observed no significant influence of phosphorus application on unmarketable yield. In agreement with this study result, Habtam*et al.* (2012) reported that further increasing the rate of the nutrient from 100 to 200 kg KCl ha^{-1} further increased unmarketable tuber yield of potato. Moreover, In contrast with this study result, Simret*etal.(*2014) reported that potassium had non-significant effect on unmarketable yield of potato.

Total tuber yield: Increasing the rate of NPS fertilizer from nil to 200 kg ha^{-1} increased total tuber yield significantly. This increment amounted to about 47.04%. However, increasing the rate of the fertilizer beyond 200 kg ha^{-1} did not increase the total tuber yield of potato. However, further increasing the rate of the fertilizer from 100 to 200 kg ha^{-1} increased the marketable tuber yield of the crop by about 12%. Beyond application 200 kg NPS ha^{-1}, total tuber yield rather decreased (Table 7). In this case, the highest or optimum marketable tuber yield was obtained already at the rate of 200 kg NPS ha^{-1}.

Similarly, increasing the rate of potassium fertilizer from nil to 100 kg KCl ha^{-1} increased the marketable tuber yield by about 18.36%. Further increasing the rate of the fertilizer to 200 kg KCl ha^{-1} increased the marketable tuber yield by about 36.93%. Thus, the response of total tuber yield to the application of potassium fertilizer was much more vigorous and continuous at each rate of the fertilizer than the response observed for application of the NPS fertilizer (Table 7). The highest total tuber yield was obtained at the rate of 200 kg KCl ha^{-1}. The maximum total tuber yield of the crop was obtained in response to the application of 200 kg KCl ha^{-1} (Table 7), which indicates that potassium is an important limiting factor for increasing productivity of the crop.

Consistent with this result, Israel *et al.* (2012) and Zelalem*et al.*(2009) reported that increasing the application rates of nitrogen and phosphorus resulted in increasing total tuber yield. Minwyelet*et al.*, (2017) and Melkamu*et al.* (2018) reported that the rate of 272 kg blended NPS ha^{-1} resulted in the production of the highest total tuber yield (47.53 t ha-1) while application of no blended NPS fertilizer produced the lowest total tuber yield (17.32 t ha^{-1}). Getachew*et al.* (2016) also reported that application of 100 kg blended NPKSZ ha^{-1} fertilizer resulted in the highest total tuber yield whereas the lowest tuber yield was obtained in response to nil application of the fertilizer.

The results of this study are also consistent with that of Wassie*et al.* (2011) who reported that total tuber yield increased in response to increasing the rate of potassium fertilizer and the highest tuber yield was obtained from K level of 150 kg ha^{-1}.Corroborating the results of this study, Habtam*et al.* (2012) also reported that further increasing the rate of the nutrient from 100 to 200 KCl ha^{-1} increased the three tuber yield components.

Partial Budget Analysis: To obtain an excellent economic return, optimum fertilizer application has great importance. The results of the study indicated that blended NPS and KCl fertilizers had given promoting benefit over the control. Partial budget analysis was done based on the view of CIMMYT Economics Program (1988) recommendations, which stated that application of fertilizer with the marginal rate of return above the minimum level (100%) is economical. As the result of this study partial budget analysis revealed that the maximum net benefit of Birr 369,654 and 389,262 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2968.69 and 2693.60% was recorded in the treatment that received the application of 200 kg blended NPS ha^{-1} and 200 kg KCl ha^{-1} fertilizer rates respectively (Table 8). However, the lowest net benefit of Birr 255,636 and 280,908 ha^{-1}and non-acceptable marginal rates of return (MRR) were obtained in both nil received plots of blended NPS and KCl fertilizers respectively. The application of 200 kg blended NPS ha^{-1} and 200 kg KCl ha^{-1} generated 114,018- and 108,354-Birr ha^{-1} more compared to in both nil received plots of blended NPS and KCl fertilizers respectively. The application of 200 kg blended NPS and KCl per hectar which gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers (>1 or 100%). 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. Based on this result, 200 kg blended NPS and KCl ha^{-1} were resulted highest adjustable marketable tuber yield (31167 and

32751 kg ha^{-1}) respectively and profitable to the farmers in the study area (Table 8).

Conclusions and Recommendation: Potato is one of the most important food security and cash crop for farmers in highland parts of Ethiopia, particularly in Guji zone where it is grown abundantly. Even though, potatoes serve as a major food source, as well as an inexpensive source of energy and good quality protein as well as very rich in nutrients and can provide nutrition to the growing global population. Twofold digit increasing world population requires producing more food in land which is steadily exhaustion and losing its fertility each year due to over exploitation and poor soil fertility managements. Most highlands of Ethiopian soil including in Guji highlands have limited potential of giving high crop yields due to the diverse and complex but declining soil fertility, increasing soil acidity (low pH).

Even though, potatoes are highly responsive to nitrogen fertilizer because of this the factors to consider when deciding on the rate of N to apply include: potato variety, yield potential or goal, growing season, soil organic matter content, and previous crop. The problem of low soil pH has led to nutrient imbalances that lead to even further decline of potato yields also nutrient imbalance hence reducing potato yields even further. Therefore, this study clearly indicate that the bottleneck problem for crop production severe soil acidity require an urgent need for appropriate use of soil health inputs (nutrients) to reserve the situation for the crops grown in the study area.

This study result, indicate that the main effect of blended NPS and KCL fertilizers influenced (days to 90% maturity, plant height, number of main stem per hill, average tuber number per hill, marketable, total tuber yield and harvest index) had highly significant ($P < 0.01$) while non-significant the main effect of blended NPS and KCL fertilizers on percent of peel content potato. From this result, it can be concluded that the interaction of blended NPS and KCL rates not affected all potato parameters.

The application of200 kg blended NPS and KCL ha^{-1} fertilizer rates produce the highest adjustable marketable tuber yield (31167 and 36390 kg ha^{-1}) and economic returns (369,654 and 389,262 ETB) respectively. Therefore, based on the results of the partial budget analysis application of 200 kg KCL ha^{-1} (200 kg KCL + 46 kg N ha^{-1}) or application of 200 kg blended NPS with 46 kg N ha^{-1} (84 kg N ha^{-1} +76 kg P_2O_5 + 14 kg S ha^{-1}) resulted in optimum tuber yield of potato. Therefore, based on this study it can be concluded that combined application of 200 kg KCL ha^{-1} (200 kg KCL + 46 kg N ha^{-1}) or application of 200 kg blended NPS with 46 kg N ha^{-1}(84 kg N ha^{-1} + 76 kg P_2O_5 + 14 kg S ha^{-1}) fertilizer ratesled to optimum potato tuber production, economic returns and recommended for potato growers in the highland areas of Guji zone

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