Advances in Crop Science and Technology
ISSN: 2329-8863
Shunka et al., Adv Crop Sci Tech 2016, 4:6
DOI: 10.4172/2329-8863.1000250
Research Article
OMICS International

Response of Potato (*Solanum tuberosum* L.) Varieties to Nitrogen and Potassium Fertilizer Rates in Central Highlands of Ethiopia

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Abstract

Field experiment was conducted at Holetta and Jeldu Agricultural Research Station in the central highlands of Ethiopia to determine the rates of Nitrogen (N) and Potassium (K) fertilizers on growth, yield and yield components of potato. 4 × 3^2 factorial treatment was arranged in completely randomized block design with three replications on plot size of 3 m × 3 m during 2014-2015 cropping season. Nitrogen (87 kg, 110 kg and 133 kg/ha), Potassium (0, 34.5 kg, 69 kg and 103.5 kg/ha) and potato varieties (Betete, Gudenie and Jalenie) were used. Data were analyzed by using SAS software Version 9.2. The interaction effect of potassium and nitrogen fertilizers did affect marketable tuber number and plant height significantly. Gudenie produced the highest marketable yield (30.53 ton/ha) in 2015 with application of 69 kg/ha potassium and 110 kg/ha nitrogen rates while lowest marketable yield (16.67 ton/ha) was obtained from Belete variety at 0 kg/ha potassium rate and 87 kg/ha nitrogen rate. From these results, it can be concluded that interaction of nitrogen and potassium rates affected significantly plant height and marketable tuber numbers. Therefore, it is better to apply 69 kg/ha potassium and 110 kg/ha nitrogen for potato production to obtain reasonable economic yield at sites similar to experimental locations.

Keywords: Potato; Potassium and nitrogen rates; Marketable; Unmarketable yield; Ethiopia

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important food crops worldwide. It ranks third after rice and wheat in terms of human consumption [1]. Among root and tuber crops, potato ranks first in volume of production and consumption, followed by cassava, sweet potato and yam. Annual world production of potato is about 330 million metric tons from 18,651,838 ha area coverage and in Africa total production is about 17,625,680 tons from total area coverage of 1,765,617 ha [2]. In Ethiopia, total area coverage of potato is nearly 0.18 million hectare from which 1.62 million ton is harvested [3]. According to Yilma [4], about 70% of cultivated agricultural land of Ethiopia is suitable for potato production. Despite high potential production environments and marked growth, the national average potato yield in farmers field in Ethiopia is only 11.1 t ha^{-1}, which is lower than the experimental yields of over 38 t ha^{-1}, which is very low compared to the world average of 17.6 t ha^{-1} [1,2,5]. The main contributing factors for under production and utilization of potatoes are lack of high yielding and diseases tolerant varieties, unavailability of quality seed and poor agronomic practices such as optimum nutrition and irrigation etc.

Low soil fertility in general and deficiency of Nitrogen (N) and Phosphorus (P) in most Ethiopian soils in particular is the most important constraint limiting potato production in Ethiopia [2]. The authors reported that, the soil fertility decline is attributed to continuous cropping, abandoning of fallowing, reduced crop rotation, removal of nutrients together with the harvested crops, reduced use of animal manure and crop residues due to their use as a fuel, which should be added to the soil and erosion coupled with low inherent fertility. The situation is exacerbated by the inherently high soil acidity with pH values of 4.02 to 4.6 being common. Most of the potato growing areas in Ethiopia have a soil pH of less than 5.5 [6,7]. A pH of less than 5.5 severely limits availability of potassium, nitrogen, phosphorus, sulphur, calcium and magnesium, while availing excessive levels of aluminum, manganese, boron, iron, copper and Zinc [8]. It is possible that this problem of low soil pH has led to nutrient imbalance hence reducing potato yields even further.

In Ethiopia, some farmers use inorganic fertilizers for increasing potato yields. However, they use only nitrogen (as Urea) and phosphorus (as DAP) since these are the only fertilizers commercially available in the local market. In addition, application of these fertilizers to potato crop is based on blanket recommendations that were formulated for potato grown on soils of certain sites in the country decades ago, that is, 165 kg Urea/ha (111 kg N/ha) and 195 kg DAP/ha (40 kg P/ha). These recommendations wholly disregard the specific physico-chemical characteristics of the varied soils on which the crop is grown as well as the dynamic nature of soil nutrient status. But application of 138 kg N and 20 kg P/ha is found to be the appropriate rate for optimum productivity of Gorebella variety on the vertisols of Debere Berhan in the central highlands of Ethiopia under rain fed conditions, which can be an insight to conduct trials for other varieties to develop optimum rate enhancing economic return [9]. When excessive nitrogen is applied, crop yield is reduced; cost of production increased and environment is polluted, especially soil and ground water is acidified [10].

Early reports by Murphy described that, favorable potassium supply, except in a few acutely deficient soils, have led researchers and farmers to ignore the need for potassium in many parts of East Africa. Consequently, potassium fertilizer is not entirely applied to crops by farmers in Ethiopia. Without application of phosphate and potassium, the yield response to increasing levels of nitrogen was smaller than when adequate amounts of P and K were applied. Therefore, all the essential nutrients should be available to the crop to realize maximum

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Received December 08, 2016; **Accepted** December 19, 2016; **Published** December 26, 2016

Citation: Shunka E, Chindi A, W/giorgis G, Seid E, Tessema L (2016) Response of Potato (*Solanum tuberosum* L.) Varieties to Nitrogen and Potassium Fertilizer Rates in Central Highlands of Ethiopia. Adv Crop Sci Tech 4: 250. doi: 10.4172/2329-8863.1000250

	Potassium levels (kg ha^{-1})	Total Tuber Yield (ton/ha)	Marketable yield (ton/ha)
	0	18.72b*	15.67b*
	34.5	19.83ab*	16.17b*
	69	20.25ab*	16.44b*
	103.5	21.72a*	18.58a*
$CV\%_{(0.05)}$		17.80	20.24

Means followed by same letter(s) are not significantly different from each other at p ≤ 0.05. *- indicate means which are significantly different at 5% level of probability. CV% - Coefficient of Variance

Table 1: Effect of potassium rates on total tuber and marketable yields.

Year	Unmarketable Tuber Number/plot	Unmarketable Tuber weight (ton/ha)	Total Tuber Yield (ton/ha)	Plant height (cm)
2014 2015	46.79b** 63.16a**	1.81b** 3.61a**	25.93b** 35.24a**	56.19b** 63.34a**
$CV\%_{(0.05)}$	30.49	23.21	20.5	14.95

Means followed by same letter(s) are not significantly different from each other at p ≤ 0.05**- indicate means which are significantly different at 1% level of probability. CV% - Coefficient of Variance

Table 2: Effect of growing year on performance of potato varieties.

Year	Total Tuber Number/ plot	Marketable Tuber Weight (ton/ha)	Total Tuber Yield (ton/ ha)	Unmarketable Tuber Number/plot	Unmarketable Tuber Weight (ton/ha)	Plant Height (cm)
Holetta Jeldu	175a** 159b**	27.9a** 18.15b**	37.55a** 23.62b**	68a** 42b**	4.31a** 1.1b**	77.02a** 42.50b**
$CV\%_{(0.05)}$	20.9	24.14	20.5	30.49	23.21	14.95

Means followed by same letter(s) are not significantly different from each other at p ≤ 0.05. **- indicate means which are significantly different at 1% level of probability. CV% - Coefficient of Variance

Table 3: Effect of growing location on performance of potato varieties.

yields. In addition to this, the information about Potassium fertilizer and its rates on potato product is also scarce in Ethiopia. Furthermore, fertilizer recommendations do not cater for potassium yet some studies have indicated response of potatoes to potassium addition on some highland parts of the country [6]. Even though the crop requirement of potassium is higher than N and P rates, the cultivation is done without Potassium fertilizer application in major potato growing areas [11]. Significantly increase in leaf potassium (K) content was indicated with applied K and showed positive correlation with tuber yield and negative correlation with frost score [12]. On the other hand potassium deficient potato crop is found less resistance to diseases and other pests, frost damage, low yielder and poor quality even though varying with variety [12]. Improved potato varieties that have been recently released in Ethiopia may differ in nutrient efficiency, and could have different optima of balanced macro-nutrient requirements for maximum yield of good quality seed tubers. However, there is limited information on the optimum requirements of balanced NK nutrition of improved potato varieties in the country. Hence, this study was initiated to investigate the main effects of nitrogen and potassium fertilizers on yield and yield component of potato varieties.

Materials and Methods

An experiment was conducted in 2014 and 2015 main cropping season at Holetta Research and Jeldu sub-center containing three factors (Jalenie, Gudanie and Belete potato varieties; 87, 110, 133 kg/ha nitrogen and; 0, 34.5, 69, 103.5 kg/ha potassium levels) which were managed in completely randomized block design with three replications. The fertilizers source used were urea (CO ($[NH_2]_2$) (46% N) and 195 kg /ha of DAP (46% P_2O_5) and Potassium nitrate (KNO_3=13% N and 46% K_2O). The Average PH H_2O (1:2.5), Exch. Acidity (cmol(+)/kg, Buck Density (g/cm^3). Total available nitrogen b and organic matter in %. Available P (PPm) were 4.26, 0.38, 1.18, 0.15, 1.50 and 6.92 respectively for Holetta growing location. Planting was carried out using sprouted tubers having uniform size for the three varieties with 10 cm depth and 75 cm distance between rows and 30 cm between plants on 3 m × 3 m plot size. The nitrogen fertilizer was applied in two split: half at planting and half at 45 days after planting as side dress at 5 cm around the root zones as reported in Teriessa [13,14]. Whole Phosphorus (as DAP) at rate of 195 kg /ha and whole Potassium fertilizer was applied during planting in the first year while whole potassium was applied at 45-55 days after planting in second growing season. Redoml at 2 kg/ha was applied to control late blight following incidence of 24-36 hours. Others cultural practices were done in the same practice as Holetta Agricultural research center recommended practice for potato production. Tuber harvesting was done once at proper physiological maturity (70% leaves withering). Data collected from those middle rows were plant height (cm), tuber fresh weight (ton) and dry weight (gm), marketable tuber number, marketable tuber yields (ton), unmarketable tuber number and weight (ton) and total tuber number. Data was subjected to analysis of variance using proc GLM (general linear model) procedure of SAS 9.2 software [15]. The means were compared with Duncan's Multiple Rage Test at 5% significance level.

Results

Based on 2014 data result, the potassium rates were affected both marketable and tuber yield ton/ha significantly ($P<0.05$) as indicated in Table 1. The highest marketable tuber yield and total tuber yield was obtained from 103.5 kg/ha even though the later was not statistically different from result of 34.5 and 69 kg/ha of potassium rates while lowest yield in ton/ha was produced from control (Table 1). The growing years also affected unmarketable tuber number and weight, total yield ton/ha and plant height highly significantly ($P<0.01$) (Table 2). In all parameters, the 2015 cropping season exceeded the 2014 production year (Table 2). This is probably due to lime application in Holleta growing location as whole and time of application of potassium rates in addition to other climatic variation between the two consecutive years. Likewise the growing location also influenced significantly ($P<0.05$) the total tuber number/plot, marketable tuber weight ton/ha, total yield ton/ha, unmarketable tuber number/plot and weight ton/ha, and plant height cm (Table 3). Regarding the location, Holetta research station

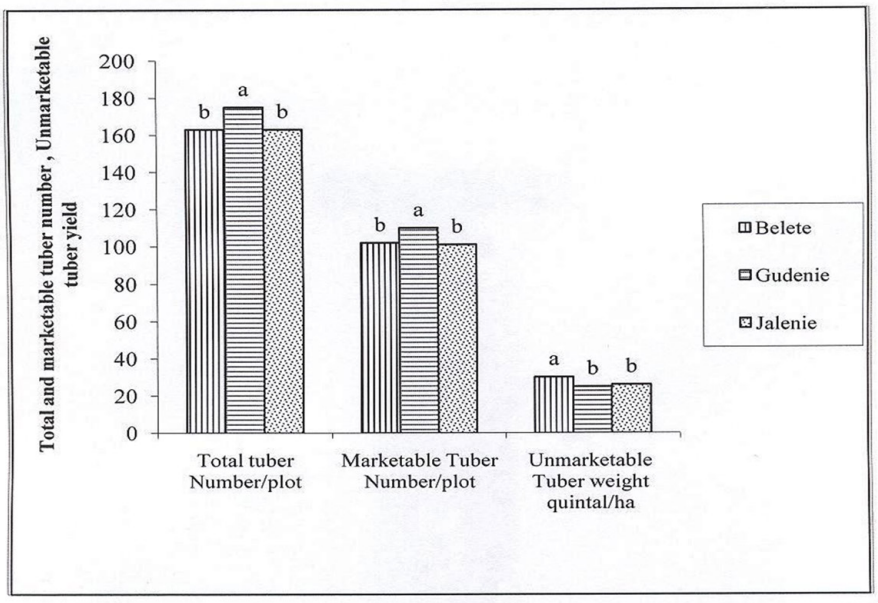

Figure 1: Varieties total and marketable tuber number, unmarketable tuber weight in quintal/ha.

Potassium levels (kg ha^{-1})	Nitrogen levels (kg ha^{-1})	Marketable Tuber Number/plot	Plant Height (cm)
0	87	100bc*	59.27bc**
	110	99bc*	59.3bc**
	133	110ab*	57.23c**
34.5	87	115a*	57.45bc**
	110	105abc*	57.57bc**
	133	101bc*	63.89a**
69	87	107ab*	59.93abc**
	110	99bc*	62.29ab**
	133	106abc*	58.77bc**
103.5	87	94c*	60.11abc**
	110	108ab*	62.66ab**
	133	109ab*	58.69bc**
CV% $_{(0.05)}$		26.04	14.95

Means followed by same letter(s) are not significantly different from each other at p ≤ 0.05. * and ** -indicate means which are significantly different at 5 and 1% level of probability, respectively. CV % - Coefficient of Variance in percent.

Table 4: Interaction effects of potassium and nitrogen rates.

provided higher value in all above mentioned parameters than Jeldu research site (Table 3).

As indicated in Figure 1, the total and marketable tuber numbers affected highly significantly (P<0.01) by varieties. The higher total and marketable tuber number was obtained from variety Gudanie while the lower was obtained from both Belete and Jalenie varieties as the two produced statistically the same, numerically they are different.

In addition, the interaction of potassium and nitrogen was affected marketable tuber number significantly (P<0.05) and plant height highly significantly (P<0.01) (Table 4). The highest marketable tuber number was obtained from 34.5 kg potassium and 87 kg/ha nitrogen while lowest yield at 0 kg/ha and 87, 110 kg/ha nitrogen as well as 103.5 kg/ha potassium and 87 kg/ha nitrogen. The highest plant height was recorded at 34.5 kg/ha potassium and 133 kg/ha nitrogen; 69 kg/ha with 87 kg/ha and 110 kg/ha nitrogen; 103.5 kg/ha with 87 kg/ha and 110 kg/ha while lowest was at 0 kg/ha potassium with all rates of nitrogen.

The interaction of potassium and variety was highly significant (P<0.01) as indicated by Figure 2. Potato variety, Gudanie produced the highest total and marketable tuber number at 0 kg/ha while Belete at 34.5 kg/ha and Jalenie at 69 kg/ha potassium rates. The lowest total and marketable tuber number was obtained at 34.5 kg/ha from Gudanie, 69 kg/ha from Belete and 103.5 kg/ha potassium from Jalenie varieties, respectively.

As indicated in Table 5 above, the interaction of nitrogen rates and varieties affected highly significantly (P<0.01) the total and marketable tuber number. At 87 kg/ha nitrogen Belete variety yielded lower total and marketable tuber number than both Gudanie and Jalenie varieties, respectively. The latter varieties were produced statistically not different total and marketable tuber number. On the other hand, at 110 kg/ha nitrogen Belete and Gudanie produced highest total and marketable tuber number than Jalenie variety. But at 133 kg/ha nitrogen all varieties were not produced significantly different total and marketable tuber number.

The growing year, nitrogen and variety affected marketable tuber number significantly (P<0.05). Highest marketable tuber number was

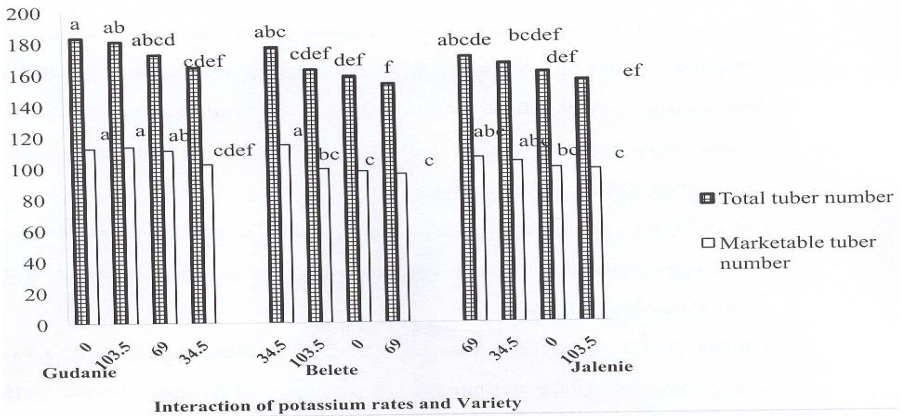

Figure 2: Interaction of Potassium rates and variety.

Nitrogen rates Kg ha^{-1}	Variety	Total Tuber Number/plot	Marketable Tuber Number/plot
87	Belete	154c**	93c**
	Gudanie	172b**	110ab**
	Jalenie	175b**	109ab**
110	Belete	168ab**	107ab**
	Gudanie	179a**	109ab**
	Jalenie	150c**	92c**
133	Belete	166ab**	105ab**
	Gudanie	174ab**	111a**
	Jalenie	163bc**	104ab**
CV% $_{(0.05)}$		20.9	26.04

Means followed by same letter(s) are not significantly different from each other at p ≤ 0.05. **- indicate means which are significantly different at 1% level of probability. CV% - Coefficient of Variance.

Table 5: Interaction effect of nitrogen rates and varieties.

Nitrogen rates kg/ha	Variety	Marketable tuber number/plot	
		2014	2015
87	Belete	100bcde*	85e*
	Gudanie	111ab*	109abc*
	Jalenie	103abcd*	116a*
110	Belete	113ab*	102abcd*
	Gudanie	102abcd*	115ab*
	Jalenie	94cde*	89de*
133	Belete	104abcd*	105abc*
	Gudanie	117a*	106abc*
	Jalenie	103abcd*	104abcd*
CV% $_{(0.05)}$		26.04	

Means followed by same letter(s) are not significantly different from each other at p ≤ 0.05. * - indicate means which are significantly different at 5% level of probability. CV% - Coefficient of Variance

Table 6: Interactions of year, nitrogen and variety.

obtained from Gudanie at 133 kg/ha nitrogen in 2014 and Jalenie at 87 kg/ha nitrogen in 2015. The lowest marketable tuber number was recorded from Jalenie at 110 kg/ha in 2014 and Belete at 87 kg/ha in 2015. The interaction of year, variety, potassium and nitrogen rates was significantly (P<0.05) affected marketable yield ton/ha. The maximum marketable yields for Belete, Gudanie and Jalenie in 2014 were 27.31, 27.04 and 23.97 ton/ha at 34.5 kg potassium and 110 kg/nitrogen, 69 kg/ha potassium and 133 kg/ha nitrogen, 69 kg/ha potassium and 133 kg/ha nitrogen, respectively.

Moreover, maximum marketable tubers of 2015 indicated that 29.68, 30.53 and 27.87 ton/ha at 34.5 kg/ha potassium and 133 kg/ha nitrogen, 69 kg/ha potassium and 110 kg/ha nitrogen, and 0 kg/ha potassium and 133 kg/ha nitrogen in 2015 for Balete, Gudanie and Jalenie, respectively. The lowest marketable yield ton/ha (18.92 ton/ha) in 2014 was produced by Jalenie variety at 34.5 kg/ha potassium and 87 kg/ha nitrogen while it was 16.16 ton/ha at 0 kg/ha potassium and 110 kg/ha nitrogen in 2015.

The interaction of growing year and location was also significant (P<0.05) (Table 6). It affected all parameters measured. As indicated in Table 7, maximum total tuber number (175) and yield (37.55 ton/ha), unmarketable tuber number (68) and unmarketable tuber weight (4.31 ton/ha), and plant height (77.02 cm) were produced at Holetta location in 2015 while maximum marketable tuber yield (28.75 ton/ha) and 114 tuber number were obtained in 2014 growing year from the

Location	Total tuber Number/ plot		Total Yield ton/ha		Marketable Tuber Number		Marketable Tuber weight ton/ha		Unmarketable Tuber Number/plot		Unmarketable Tuber weight ton/ha		Plant Height cm	
Growing year	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Holetta	165b**	185a**	31.8b**	43.3a**	114a**	99c**	28.75a**	27.04b**	49b**	87a**	2.7b**	5.9a**	74.44b**	79.61a**
Jeldu	169b**	148c**	20.06d**	27.18c**	96c**	109ab**	16.64d**	19.67c**	45bc**	39d**	0.9d**	1.3c**	37.94d**	47.07c**
$CV\%_{(0.05)}$	20.9		20.5		26.04		24.14		30.49		23.21		14.95	

Means followed by same letter(s) are not significantly different from each other at p ≤ 0.05. ** - indicate means which are significantly different at 1% level of probability. CV% - Coefficient of Variance

Table 7: Interaction of growing year and location.

same location. Minimum values measured were obtained from Jeldu location in 2014 year.

Discussion

Based on 2014 data result, the potassium rates affected the total tuber yield and marketable tuber yield significantly (P<0.05). The highest tuber yield of (21.72 kg/ha) and marketable yield (18.58 kg/ha) was obtained at 103 kg/ha potassium than other rates. This result is similar with the finding of Shahid and Moinuddin [12]. It also agrees with finding of which mentioned yield increment due to applied potassium through increase of number and size of tubers [11]. According to Bansal and Trehan [11] there is significant yield variability in relation to variety and growing location which make it consistent with present experiment as variety, growing year and location affected highly significantly yield and yield component of the potato product. Response of potato to NPK varies with variety, soil characteristics and geographical escarpment [16]. These results again correlated with the investigations results of Lamberti et al.; Vreugdenhil et al.; Trehan; Gumul et al. [17-20]. The interaction of potassium and nitrogen was also produced significantly different marketable tuber number and plant height while potassium and variety interaction provided significantly different total and marketable tuber number which have similar concept with the experimental results of Tally and Berug et al. [21,22]. The interaction of nitrogen and variety was also highly significant. Kathryn [23] reported that, increment of yield of potato with applied K and N. Similar concept was also noticed by Allison et al. [24]. Supporting investigations results were found in Anabausi et al.; Tawfik; Al-Moshileh et al.; Sharmila and Santhu [25-28]. On other hand, Locascio et al. [29] did not find an effect on the crop yield with increasing K rate which may be due to varieties used response to potassium fertilizer and growing location soil and climatic condition variation with present experiment. Ismail and Abu-Zinada [30] indicated that interaction of potassium and nitrogen significantly increased the tuber number and yield. There was variability to applied K by variety as mentioned in experimental results of Moinuddin et al.; Trehan [19,31]. According to Singh and Lal [32] the interaction of N and K has significantly affected the plant height and yield components. It also further mentioned ways of boosting yields such as increment of tuber size and number as well as total yield as a result of potassium and nitrogen rate applied. In addition, potato produced by potassium application has less weight loss and highest resistance to diseases. Moinuddin et al.; Ummar and Moinuddin [33,34] also observed increase in potato tuber yield due to potassium application up to 120 kg K_2O ha^{-1}. The report of Eleiwa [35] indicated increase yield with increasing NPK, the highest yield was attained at (120:80:100) rates, respectively. Moreover, significant response of Jalenie potato variety to potassium fertilizer is identified Geremew et al. [36].

Conclusion and Recommendation

According to these results, the main effect nitrogen was not affected any measured parameters of the varieties under experiment. But the interaction of potassium and nitrogen affected the marketable tuber number and plant height highly significantly. The interaction of potassium and variety showed significant influence on total and marketable tuber number. The interaction of growing year, nitrogen and variety also caused significant effect on marketable tuber number per plot. The interaction of growing year, potassium and nitrogen rates with variety was also brought significantly effect on tuber yield ton/ha. The maximum marketable tuber yield was attained in 2015 at 69 kg/ha potassium and 110 kg/ha nitrogen from Gudanie variety. Therefore, it is better to apply 69 kg/ha potassium and 110 kg/ha nitrogen to potato production for reasonable yield at sites similar to experimental locations. However, further research on time of application will be required in relation to locations and the rates of potassium and nitrogen.

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Citation: Shunka E, Chindi A, W/giorgis G, Seid E, Tessema L (2016) Response of Potato (*Solanum tuberosum* L.) Varieties to Nitrogen and Potassium Fertilizer Rates in Central Highlands of Ethiopia. Adv Crop Sci Tech 4: 250. doi: 10.4172/2329-8863.1000250