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Open Access Journal of Agricultural Research
ISSN: 2474-8846

Effect of Potassium Fertilizer Rate on Growth, Yield and Yield Related Parameters of 'Irish Potato (*Solanum Tuberosum* L.) at Bale Highlands

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Research Article

Volume 6 Issue 1

Received Date: December 12, 2020

Published Date: January 19, 2021

DOI: 10.23880/oajar-16000257

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 constraint 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 on-farm experiment was conducted at Dinsho and Sinja, south-eastern Ethiopia, to assess the effect of potassium fertilizer rate on yield and yield related parameters of 'Irish potato (*Solanum Tuberosum* L.) at Bale Highlands. Factorial combinations of two potato varieties (Ararsa and Moti) and five rates of potassium fertilizer (0, 25, 50, 75 and 100 kg K ha^{-1}) were laid out in a randomized complete block design (RCBD) with three replications.

Analysis of variance showed that the main effects of potassium fertilizer significantly influenced (days to 50% flowering, plant height, number of tuber per plant, number of marketable tuber per plot, marketable tuber yield and total tuber yield) had highly significant ($P < 0.01$) while non-significant for days to 90% maturity, number of unmarketable tuber per plant and unmarketable tuber yield. An improved varieties Ararsa and Moti were produce the highest marketable tuber yields of 21.23 t ha^{-1} and 19.50 t ha-1 respectively, with application of 100 kg KCl ha^{-1} and with the application of recommended rate of NP fertilizer while the lowest marketable yields of 15.01 t ha^{-1} and 14.96 t ha-1 from Ararsa and Moti Varieties, respectively, were obtained from unfertilized KCl fertilizers treatment, respectively. The economic analysis revealed that the highest net return of (187170 and 169620 ETB ha^{-1}) with marginal rate of return (4764.29 and 1185.71%) were recorded for varieties of Ararsa and Moti respectively, at 100 kg KCl ha^{-1}. Therefore, it can tentatively be concluded that application of 100kg KCl ha^{-1} and recommended rate of NP fertilizer best to optimum tuber production and economic returns for potato at Bale Highlands.

Keywords: Potato; Potassium; Fertilizer; Rate; Yield

Abbreviations: LSD: Least Significant Difference; GB: Gross Benefit; TVC: Total Variable Cost; MRR: Marginal Rate of Returns; SARC: Sinana Agricultural Research Centre.

Introduction

Potato (*Solanum Tuberosum* L.) is one of mankind's most valuable food crops and mainstay in the diets of people in many parts of the world [1]. It is the fourth most important crop in the world after wheat, maize and rice with 314.1 million tons of annual production on 18.1 million hectares of land [2]. Potato is an important source of food which contains high levels of carbohydrate, protein, vitamins and minerals. It is also source income, and employment opportunity in developing countries [3]. Due to its correct balance between protein and calories, it is considered a good weaning food and these traits make it an efficient crop in combating world hunger and malnutrition [4]. The commercial value of potatoes is increased considerably when they are processed into edible products that appeal to consumers on flavor, texture, appearance, and most of all convenience [5]. Potato consumption has increased in the developing world, and over the last decade world potato production has increased at an annual average rate of 4.5 percent. Furthermore; Kirkman MA [5] has estimated that global consumption in processed form will increase from 13% of total food use in 2002 to nearly 18% by 2020.

In Ethiopia the potential yield of potato can reach up to 50 t ha^{-1} Surendra RJ [6], but the average national potato production is 10.5 t ha^{-1}, while progressive farmers who use improved agronomic practice attained yields of 25 t ha^{-1}. The major production problems that account for such low yield are unavailability and high cost of seed tubers, lack of well adapted cultivars, poor agronomic practices, diseases, insect pests, inadequate storage, transportation and marketing facilities [7]. Low soil fertility is one of the most important constraints limiting potato production. Muriithi MM [8] and also Tekalign M [9] reported that nitrogen and phosphorus are deficient in most Ethiopian soils and thus application of these nutrients could significantly increase crop yields.

Potato is a high nitrogen (N), phosphorus (P) and potassium (K)-demanding crop. Deficiency of any or combinations of these nutrients can result in retarded growth or complete crop failure under severe cases Khiari L [10]. Nitrogen is the one most often limiting for potato growth; application of fertilizer N is necessary to ensure profitable potato production and, in general, N application increases the proportion of larger-sized tubers Zebarth BJ [11]. Phosphorus has various effects on tuber quality, since it functions in cell division and synthesis and storage of starch in the tubers Houghland GVC [12]. Thus, P can increase the size and percentage of dry matter (DM) (indicated by specific gravity) of the tubers Rosen CJ [13]. Potassium deficiencies reduce the yield, size and quality of the potato crop Mikkelsen R [14].

There was a general understanding that Ethiopian soils are rich in K and there was no need for its application based on the research conclusion of Murphy HF [15] some 40 years ago. However, with time it is likely that in some soils deficiency of K could occur due to extensive deforestation, a high incidence of soil erosion, crop nutrient removal, and continuous cropping, and inadequate and imbalanced use of organic and inorganic fertilizers Wassie HB [16]. The continuous cropping with no or insufficient K fertilization has impoverished soils of their native K fertility Shahid U [17].

Moreover, very little information is available in the country with regard to the influence of potassium fertilizers on the growth, yield, and quality of potato. Potato has relatively high potassium requirement in comparison to other vegetables, and so potassium containing fertilizers should be applied in potato fields for high yield production. Adequate potassium fertilizer application can be useful because it makes potato plants adapted to the environmental stresses and may lead to increased resistance of potato to some pests Al-Moshileh AM [18]. There is no information regard to the influence of potassium fertilizer on potato production at Bale Highlands.

Therefore, the objectives of the study were:

- To assess the effect potassium fertilizer on the tuber yield and yield related parameters of potato in case of Bale Highlands; and
- To identify economically feasible potassium fertilizer rate for potato production.

Materials and Methods

Description of Study Area

The experiment was conducted at Dinsho and Sinja during 'Gana' cropping season for three years from 2014-2016. Both areas have bimodal rainfall patterns. The soil type for both areas is Vertisols. The major crops grown widely in the area are cereals (wheat, barley, maize and tef, pulses (chickpea, field pea, faba bean, and lentil) and vegetables (onion, garlic, potato and tomato) under rain fed and irrigation.

Treatments and Experimental Design

The treatments consisted of factorial combination of two potato varieties (Ararsa and Moti) and control (no fertilizers applying), recommended rate of NP fertilizer, NP + 25 kg ha^{-1} of K, NP + 50 kg ha^{-1} of K, NP + 75 kg ha^{-1} of K and NP + 100 kg ha^{-1} of K. The experiment was laid out in a randomized complete block design in three replications. The potato varieties Ararsa and Moti which were released by Sinana Agricultural Research Centre (SARC) in 2006 and 2012, respectively, were used as planting material while K2SO4 is used as the source of fertilizer.

Experimental Procedure and Field Management

The experimental field was ploughed and disked by tractor and pulverized to a fine tilth by hand digging. Each plot contained four rows of potato plants, with each row accommodating 10 plants. The gross plot size of 3 m x 3 m (9 m2) which contain four rows and the tubers were seeded at required spacing (0.75 m x 0.3 m) between rows and plants, respectively. Plants in the one outer row as well as those at both ends of each row were not considered for data collection to avoid edge effects. Weeding and other agronomic practices were applied as required by the crop.

Data Collected and Measurement

Crop Phenology and Growth Parameters

Days to 50% of flowering (DF): it was recorded as the number of days from date of emergence to the appearance of first flower in 50% of the plants based on visual observation. **Days to 90% maturity (DM):** It was determined by counting the number of days from emergence to the days when more than 90% of the plants in a plot attained physiological maturity. Plant height (cm): refers to the height from the base to the apex of the plant. It was determined by measuring the height of 5 randomly taken plants per plot using a meter from the central four rows at flowering (or tuber initiation).

Yield Components and Yield:

Average Tuber Number per Hill: This was recorded as the actual number of tubers to be collected from 5 matured plants at harvest.

- **Marketable Number of Tuber per Hill:** This was recorded as the number of marketable tubers to be collected from 5 matured plants at harvest.
- **Unmarketable Number of Tuber per Hill:** This was recorded as the number of unmarketable tubers to be collected from 5 matured plants at harvest.
- **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.
- **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.

Statistical Data Analysis

All crop data collected were subjected to analysis of variance (ANOVA) procedure using GenStat 16th edition software [19]. Comparisons among treatment means with significant difference for measured characters were done by using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

Economic Analysis

The economic analysis was carried out by using the methodology described in CIMMYT [20] in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Ethiopian 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 fertilizer (the costs of KCl and the application costs). Yield from experimental plots was adjusted downward by 10% for management difference, to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. Total variable cost (TVC) (ETB ha^{-1}) was calculated by summing up the costs that vary, including the cost of NP and KCl fertilizer and the application costs of NP and KCl. Based on partial budget procedure described by CIMMYT (1998), the variable costs including the KCl fertilizer price (12 ETB kg^{-1}), price of potato during harvesting = Birr 10 ETB kg^{-1}, and labor cost involved for application of KCl fertilizer (3 person's ha^{-1} for 25 and 50 kg KCl ha^{-1}, 4 person's ha^{-1} for 75 and 100 kg KCl ha^{-1} and 4 person's NP (r) ha^{-1} each 120 ETB day^{-1} for each treatment was recorded and used for this analysis. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, harvesting and threshing were considered the same for all treatments or plots.

Results and Discussion

Crop Phenology and Growth Parameters of Potato

Days to Flowering and Maturity: The results from the analysis of variance indicated that application of the potassium fertilizer have a highly significant ($P < 0.01$) effect on days to 50% flowering but not to attain 90% physiological maturity in potato (Tables 1). Application of K at the rate of 100 kg K2O ha^{-1} and recommended rate of NP delays date of flowering by 10 days compared to unfertilized treatment. The lowest days to flowering was recorded in the control. The present study concludes that the effect of K fertilization prolonged the days to flowering and not affect the days to maturity. In line with this result Ayalew [21], reported that potassium fertilization did not affect the time to reach physiological maturity. This result is consistent also with that of Habtam Setu [22] who reported that increasing potassium fertilizer rate prolonged the days required to attain 50% flowering in potato.

Plant Height: The plant height was highly significantly ($P < 0.01$) influenced by application of the potassium fertilizer.

The tallest plant height (46.67 cm) was recorded due to the effect K fertilizer rate at 100 Kg KCl ha^{-1} and recommended rate of NP from Moti variety while the lowest plant height 38.13 cm was obtained at the control from Ararsa variety. In general, the tallest plant height was obtained at the fertilized; whereas the shorter at the unfertilized once (Table 1). This result is in agreement with the findings of Shunka E [23] reported that application of higher rates of potassium resulted in higher plant height of potato.

K (Kg Ha^{-1})	NP (Kg Ha^{-1})	Variety	Days To 50% Flowering	D Days To 90% Maturity	Plant Height	Tuber Number Per Plant
100	NP(r)	Moti	48.00 fg	119.3 a	46.67 a	13.70 b
75	NP(r)	Moti	48.00 fg	119.0 a	45.33 ab	12.80 bc
50	NP(r)	Moti	49.00 def	118.7 a	44.20 bcd	12.40 bc
25	NP(r)	Moti	50.33 cd	118.3 a	42.40 de	11.47 cde
0	NP(r)	Moti	55.33 b	118.3 a	40.47 e	10.87 de
0	0	Moti	57.33 a	118.3 a	37.33 f	9.07 f
100	NP(r)	Ararsa	47.33 g	118.3 a	45.07 abc	15.63 a
75	NP(r)	Ararsa	48.33 efg	118.3 a	44.80 abcd	13.57 b
50	NP(r)	Ararsa	49.33 def	118.3 a	44.47 abcd	12.67 bc
25	NP(r)	Ararsa	49.67 cde	118.3 a	42.87 cd	12.03 cd
0	NP(r)	Ararsa	51.00 c	118.7 a	40.40 e	11.43 cde
0	0	Ararsa	57.33 a	119.0 a	38.13 f	10.30 ef
LSD (0.05)			1.38	NS	2.18	1.32
CV (%)			1.6	0.7	3	6.4

Means in a column with the same letter (s) are not significantly different at 5% probability level; LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; NS= non-significant, K = potassium fertilizer, NP(r) = recommended rate of nitrogen and phosphorous fertilizer.

Table 1: Main effects of K fertilizer on days to 50% flowering, days to 90% maturity and plant height of Potato.

Effect of K Fertilizer Rates on Yield and Yield Components of Potato

The number of tuber per plant, number of marketable tuber per plant, weight of marketable tuber per plot and total yield were highly significantly ($P < 0.01$) influenced by application of the potassium fertilizers while number of unmarketable tuber per plant and weight of unmarketable tuber per plot were not significantly influenced by application of the potassium fertilizer.

Tuber Number per Plant: The highest number of tubers per plant (15.63) was recorded at 100 Kg KCl ha^{-1} of K fertilizer application with recommended rate of NP fertilizer from Ararsa variety while the lowest number of tubers per plant (9.07) was recorded from no fertilizer application on Moti variety. This shows that potassium application had vigorous effect on tuber production. These results are consistent with that of Daniel ZZ [24] who reported that number of tubers per potato plant increased in response to increasing the rate of potassium application. 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 more number of tubers per plant [4].

Number of Marketable Tubers per Plot: The highest number of marketable tubers per plot was obtained from 75 kg KCl ha^{-1} of K fertilizer application with recommended rate of NP fertilizer from Ararsa and Moti varieties while the lowest number of marketable tubers per plot was recorded from no fertilizer application on Ararsa and Moti varieties (Table 2).

Number of Un Marketable Tubers Per Plot: The difference in un marketable tubers per plot was observed to be non-significant among varieties of potato and KCl fertilizers.

Marketable Tuber Yield: The highest weight of marketable tubers per plot was obtained from 100 Kg KCl ha^{-1} of K fertilizer application with recommended rate of NP fertilizer on Ararsa variety while the lowest number of marketable tubers per plot was recorded from no fertilizer application on both Ararsa and Moti varieties (Table 2). In agreement with this; Al-Moshileh AM [18] reported that marketable tuber yield was significantly improved with increasing the potassium level.

Unmarketable Tuber Yield: The difference in unmarketable tuber yield was observed to be non-significant among varieties of potato and KCl fertilizers.

Total Tuber Yield: The highest tuber yield (23.64 t ha^{-1}) was recorded from variety Ararsa at rate of 100 kg KCl ha^{-1} fertilizer with recommended rate of NP while the lowest tuber yield was recorded from variety Moti without fertilizer application and it was statistically at par with variety Ararsa without fertilizer application. Zameer MK [25] was reported a significant higher tuber yield with K application rate at K2O 150 Kg ha^{-1} than NP treatment. In addition, Westermann DT [26] also reported a significant increment in tuber yield due to K fertilizer only on the K responsive soils (Table 2).

K (Kg ha^{-1})	NP (Kg ha^{-1})	Variety	Number of marketable tuber per plant	Number of unmarketable tuber per plant	Marketable tuber Yield (t ha^{-1})	Unmarketable tuber Yield (t ha^{-1})	Total tuber yield (t ha^{-1})
100	NP(r)	Moti	72.67 c	17.50 a	19.28 b	1.33 a	21.51 b
75	NP(r)	Moti	80.33 ab	17.50 a	18.68 bcd	1.48 a	21.16 bc
50	NP(r)	Moti	66.83 d	17.50 a	18.30 cd	1.54 a	20.83 bcd
25	NP(r)	Moti	61.17 e	17.67 a	17.71 cd	1.37 a	20.38 d
0	NP(r)	Moti	45.67 f	17.50 a	16.96 e	1.48 a	19.24 e
0	0	Moti	32.83 g	17.50 a	14.96 f	1.48 a	16.64 f
100	NP(r)	Ararsa	76.67 b	18.33 a	21.23 a	1.41 a	23.64 a
75	NP(r)	Ararsa	81.67 a	17.50 a	18.96 bc	1.51 a	21.47 b
50	NP(r)	Ararsa	71.17 c	18.50 a	18.54 cd	1.49 a	21.00 bcd
25	NP(r)	Ararsa	65.50 d	18.17 a	18.29 cd	1.46 a	20.71 cd
0	NP(r)	Ararsa	58.67 f	17.50 a	18.01 d	1.38 a	20.28 d
0	0	Ararsa	35.50 g	17.50 a	15.04 f	1.34 a	16.92 f
LSD (0.05)			3.94	NS	6.73	NS	6.9
CV (%)			3.7	3.5	2.2	6.3	2

Means in a column with the same letter (s) are not significantly different at 5% probability level; LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; NS= non-significant, K = potassium fertilizer, NP(r) = recommended rate of nitrogen and phosphorous fertilizer.

Table 2: Main effects of K fertilizer on Number of marketable tuber per plant, Number of unmarketable tuber per plant, marketable tuber yield, unmarketable tuber yield and total yield of Potato.

Economic Evaluation

Partial budget analysis revealed that the highest net benefit (187170 and 169620 ETB ha^{-1}) with marginal rate of return (4764.29 and 1185.70%) were recorded for varieties of Ararsa and Moti respectively; both at 100 kg KCl ha^{-1} with recommended rate of NP for potato (Table 3). The dominated treatments according to the dominance analysis were eliminated from further economic analysis. To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as a worthwhile option to farmers, the marginal rates of return (MRR) need to be at least between 50% and 100% [20]. Thus, to draw farmers' recommendations from marginal analysis in this study, 100% return to the investment is reasonable minimum acceptable rate of return. Accordingly, application of 100 kg KCl ha^{-1} with marginal rate of returns (4764.29 and 1185.70% MRR) for varieties of Ararsa and Moti respectively, were above the minimum acceptable rate of return. Therefore, application of 100 kg KCl ha^{-1} and recommended rate of NP fertilizer for varieties Ararsa and Moti were superior rewarding treatments and these fertilizer rates can be recommended for those varieties in Dinsho and other areas with similar agro-ecology condition.

K (Kg ha^{-1})	NP (Kg ha^{-1})	Variety	Average yield (kg ha -1)	Adjusted yield by 10% down (kg ha^{-1})	GFB (ETB ha-1)	TVC ETB ha-1)	NB (ETB ha-1)	MRR (%)
0	0	A	15040	13536	135360	0	135360	
0	NP (r)	A	18010	16209	162090	2100	159990	1172.86
25	NP (r)	A	18290	16461	164610	2640	161970	366.67
50	NP (r)	A	18540	16686	166860	3060	163800	435.71
75	NP (r)	A	18960	17064	170640	3480	167160	800
100	NP (r)	A	21230	19107	191070	3900	187170	4764.29
0	NP (r)	M	14960	13464	134640	0	134640	D
0	NP (r)	M	16960	15264	152640	2100	150540	2035
25	NP (r)	M	17710	15939	159390	2640	156750	1150
50	NP (r)	M	18300	16470	164700	3060	161640	92.86
75	NP (r)	M	18680	16812	168120	3480	164640	714.29
100	NP (r)	M	19280	17352	173520	3900	169620	1185.71

Where GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D = dominated treatments; Cost of NP 1500.00 Birr 100 kg^{-1}; Cost of KCl 1200.00 Birr 100 kg^{-1}; Labour cost for KCl fertilizer application = 4-person day ha^{-1}, at 120 ETB per day; sale price of fenugreek seed 2500 Birr per 100 kg during harvest on farm.

Table 3: Partial budget analysis result for potassium and NP fertilizer rate on potato at Dinsho and Sinja in 2017/18 main cropping season.

Summary and Conclusion

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. Most highlands of Ethiopian soil including in Bale highlands have limited potential of giving high crop yields due to declining of soil fertility. This might be caused by land degradation due to up slop cultivation, flooding, soil acidity, limited use of chemical fertilizers is some major negative intervention slow agricultural productivity in Ethiopia.

The main effect of blended KCl with recommended rate of NP fertilizers influenced (days to 50% flowering, plant height, number of tuber per plant, number of marketable tuber per plot, weight of marketable per plot and total tuber yield) had highly significant ($P < 0.01$) while non-significant for days to 90% maturity, number of unmarketable tuber per plant and weight of unmarketable tuber per plot. An improved varieties Ararsa and Moti were produce the highest marketable tuber yields of 21.23 t ha^{-1} and 19.50 t ha^{-1} respectively, with application of 100 kg KCl ha^{-1} and with the application of recommended rate of NP fertilizer while the lowest marketable yields of 15.01 t ha^{-1} and 14.96 t ha^{-1} from Ararsa and Moti Varieties, respectively, were obtained from unfertilized KCl fertilizers treatment, respectively.

The partial budget analysis revealed that maximum net benefit of Birr 187170 and 169620 ha^{-1} with an acceptable marginal rate of returns (MRR) 4764.29 and 1185.71% was recorded in the treatment that received 100 kg KCl ha^{-1} fertilizer rates from Ararsa and Moti varieties, respectively. However, the lowest net benefit of Birr 135360 and 134640 ha^{-1} and non-acceptable marginal rates of return (MRR) were obtained in both Ararsa and moti varieties received no KCl fertilizers respectively. Therefore, based on the results of the partial budget analysis application of 100 kg KCl ha^{-1} with recommended rate of NP fertilizer resulted in optimum tuber yield of potato and it can be tentatively recommended for farmers for production of potato in the study area.

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