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Effect of different rates of potassium fertilizer on potato (*Solanum tuberosum* L.) yield and yield components under Hadiya Zone, Southern Ethiopia

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Abstract

A field experiment was conducted at Wachemo University (Lambuda Research site) from January to October 2018 under rain fed to assess the response of different rates of Potassium (K) on yield and yield components of potato tuber. The treatments consisted of four different rates of Potassium (K) (0 Kg KCL, 50 KCL Kg, 100 KCL Kg and 150 KCL Kg). The treatments were arranged in a randomized complete block design RCBD) with three replications. There were a significant interaction effect of the different rates of Potassium (K) ($P<0.05$) on plant height, number of main stems per plant, average tuber weight, tuber number per plant, total tuber yield, marketable tuber yield, unmarketable tuber yield, large tuber mean yield, medium tuber mean yield, small tuber mean yield. The highest plant height (75.09 cm) was recorded with application of 100 Kg KCL. The highest (7.40) number of main stems was recorded with 100 Kg KCl.The highest total tuber yield (18.64 t/ha) was obtained from application of 150 Kg KCl. The highest (10.95 t/ha) larger tubers was recorded with 150 Kg KCl. Application of 150 Kg KCl produced the highest (3.13 t/ha) medium sized tubers. The highest small tuber (2.38 t/ha) was recorded from control treatment (0 Kg KCl). Application of 100 Kg KCl gave highest (19.98%) dry matter content. The higher (1.077) tuber specific gravity was obtained with application of both 100 and 150 Kg KCl. Generally, the applications of higher rates of potassium (100 and 150 Kg) were advisable for the production of higher tuber yield of potato, and to be suggested for quality potato production at Hadiya area.

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Introduction

Potato (*Solanum tuberosum*L.) 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. In Ethiopia the potential yield of potato can reach up to 50 t/ha (Joshi*et al.*, 2009), but the average national potato production is 10.5 tones/ha, while progressive farmers who use improved agronomic practice attained yields of 25 tones/ha.

The total area cropped with potato in Ethiopia is 160,000 ha (Gildemacher *et al.*, 2009), which is very low compared to the existing potential as the crop can be grown on about 70% of the 10 million hectares of arable land in the country (FAO, 2008). The national average yield is 7.2 tons ha^{-1}, which is very low compared to the world's average of 16.4 tons ha-1 and to other potato producing countries of the world, such as the Netherlands (40 tons ha^{-1}), Germany (28 tons ha^{-1}), Egypt (17.4 tons ha^{-1}) and Burundi (11 tons ha^{-1}) (FAOSTAT, 2010). On the other hand, the potentially attainable average yields of the crop on research and farmers' fields are 40 and 20 tons ha-1, respectively (MOARD, 2009). The gap between the potential yield and the current average national yield per unit area of land could be attributed to many diverse and complex biotic, abiotic, and human factors. Some of the production constraints which have contributed to the limited production or expansion of potato in Ethiopia include lack of good quality planting materials, weeds, diseases and insect pests, improper time of planting and harvesting, and poor soil fertility management practices. According to Muriithi and Irungu(2004), low soil fertility is one of the most important constraints limiting potato production in eastern Africa.

Potassium (K) is one the essential elements required by plants for their growth and development (Wassie and Shiferaw, 2011). Potassium is particularly important in helping plants adapt to environmental stress such as drought, improved winter hardiness and confer plants tolerance to frost, diseases and insect pests (Brady and Weil, 2002). In Ethiopia, so far there was a general understanding that Ethiopian soils are rich in K and there was no need for its application since 40 years ago. The intensive cropping and the increased use of nitrogen fertilizer after this long period might have lowered the availability of K in the soil (Abay and Sheleme, 2011).

Major factors contributing to such depletion are soil erosion, soil acidity, fixation of phosphorus (P), and leaching in respect of nitrogen (N) and potassium (K), further accelerated by deleterious land use practices resulting from high population pressure. Tamirie (1989) speculated that indiscriminate clearing of forests, complete removal of crop residues, uncontrolled grazing, and low fertilizer inputs, absence of soil and water conservation measures and crop rotations and above all poor soil management practices contribute to accelerated soil erosion. Soil erosion is particularly high on soils without crop cover thereby enhancing soil nutrient depletion, which emphasizes the need for optimum nutrient management for higher crop productivity (James *et al.*, 2020).

Potato demands high level of soil nutrients due to relatively poorly developed and shallow and coarse root system in relation to yield. Compared with cereal crops, potato produces much more dry matter in a shorter cycle (N'Dayegamiye *et al.,* 2017). This high rate of dry matter production results in larger amounts of nutrients removed per unit time, which generally most of the soils are not able to supply. Hence, nutrient application from external sources as fertilizers becomes crucial for achieving high yields (Abebe *et al.*, 2016).

Potato is a heavy remover of soil potassium in particular and is the nutrient taken up in the greatest quantity; tubers remove 1.5 and 4.5 times as much potassium as the amount of nitrogen and phosphate, respectively. Potato is regarded as an indicator for crop potassium availability because of the high potassium requirement (Bishwoyog and Swarnima, 2016). Furthermore, high mobility of nitrogen and high affinity of phosphorus and potassium for chemical reactions and fixation in the soils put these plant nutrients on the priority list in soil fertility management studies. There is a claim that potassium is least deficient in Ethiopian soils and that the soils have good potassium supplying power (Habtam *et al.*, 2018). However, this claim may not apply to acidic soils. The highly weathered soils have low exchangeable potassium (below 0.3 milliequivalents per 100 g of soil). Results from analysis of soils of Assosa Research Agricultural Center (AsARC) in 2011 indicated very low available P and exchangeable potassium (0.85 ppm and 0.157 milliequivalents per 100 g, respectively). These values are very low according to Mengel and Kirkby (2004). This realized that, the soils in the southern Ethiopia are acidic due to the high precipitation that leads to lose of basic cations by leaching.

In a general view of the fact that Ethiopian soils are poor in fertility and have problem of low soil pH, phosphorus fixation, and N and K leaching, and realizing the importance of fertilizers in potato production, the use of inorganic fertilizers in potato production for optimum yield and quality tuber production is vital.

Despite the very low levels of available soil potassium and generally yields of the potato crop might be low in response to this nutrient; no systematic studies have been conducted to elucidate the problem. Thus, there is little information on the response of the crop to fertilizers especially in Hadiya area in particular. Fertilizer practices in the area have been mainly based on blanket recommendations. 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. Therefore this research is aimed at investigating the effect of different rates of potassium fertilizer on the yield and yield components of potato.

Materials and methods

Description of the study site

The experiment was carried out at Wachemo University Lambuda Agricultural Research site. The experiment was conducted under rain fed condition from June to October 2018. The study site was selected based on their suitability interms of climate and soil conditions for higher potato production potential.

Experimental treatments and design

The treatments used in this study consist of four levels of potassium that was 0, 50,100& 150 Kg ha^{-1} of KCl. The recommended N rate of 110 Kg/ ha and 90 P_2O_5 kg/ha would be applied to all treatments equally. The entire rate of P, K and half of N fertilizers would be applied at the time of planting and the remaining half of N was applied 45 days after planting to support the foliage development. The fertilizers like Urea (46% N), Triple Super Phosphate (46% P_2O_5), and Potassium Chloride (62% KCl) was used as fertilizer source for N, P and K respectively.

The experiment was laid out in Randomized Complete Block Design (RCBD), with three replications. Medium size and well sprout Gudane variety of potato tubers would be planted at recommended spacing of between rows (70 cm) and between plants (30 cm). A distance of 1 meter would be maintained between plots and 1.5 m between the blocks.

The size of each plot is 3mx3m (9m^2) and total plot size attains 216m^2. Each plot has four rows which hold 10 plants or hills. Other required agronomic practices are depending on the recommendation of potato.

Experiment materials

The experiment materials were potato tuber (Gudane variety) and potassium fertilizer (K). The experiment materials were obtained from Holleta Research center.

Methods of data analysis

The data were checked for all ANOVA assumptions. The collected data were analyzed statically by using the analysis of variance (ANOVA) techniques and treatment means were subjected to SAS software for comparison at 5% Least significance difference (LSD).

Results and discussion

Phonological growth

The analysis of variance indicated that the different rate of potassium (K) for potato production was no effect on phonological data. This may indicated the K has no influence on potato days to emergence, days to flowering and days to maturity.

The current investigation revealed with the work of Ayyub *et al.* (2011) which indicated the days to emergence, flowering and days to maturity showed no significances difference amongst the treatments.

Table 1. Effects different rates of potassium (K) on growth parameters of potato in 2018 at Lambuda research site.

Treatments		Growth parameters	
	K (Kg)	Number of main stems	Plant height (cm)
	0	3.29^{d}	64.23^{cd}
	50	5.65^{c}	65.79^{c}
	100	7.40^{a}	75.09^{a}
	150	6.10^{ab}	70.44^{b}
CV (%)		5.95	4.17
LSD (5%)		0.47	4.65

Means with the same letter (s) with in a column of a variable were not significantly different at (P < 0.05). CV=Coefficient of variation and LSD=Least significance difference.

Growth parameters

Plant height

The K fertilizer was significantly (P<0.05) influenced potato plant height (Table 1). The highest plant height (75.09 cm) was recorded from 100 Kg potassium (K), while the shortest plant height (65.23 cm) was recorded from control (0 Kg) treatment (Table 1). The increment in vegetative growth of potato plants with potassium (K) at 100 Kg may be due to the role of potassium on plant nutrition, i.e. promotion of enzymes activity and enhancing the translocation of assimilates and protein synthesis (Salim *et al.*, 2014). The lowest plant height was obtained at the control compared to the fertilized treatments (Niguse*et al.,* 2016).

Number main stems

Number of main stems had shown gradual and significant (p<0.05) increase within increasing K levels up to 100 Kg. according to Daniel *et al.* (2016), the number of main stem the potato was influenced by the application of K fertilizer. In contrary to the present study, the number of main stems was influenced by the application of K fertilizer and was positively correlated with the applied K but most of the K rates gave a lower stem number though the number of main stems neither decreased nor increased with increasing the rates of K application (Niguse *et al.,* 2016). The maximum numbers of main stems were found with the application of high potassium while minimum numbers of stems were found with lower supply of potassium (Ayyub *et al.,* 2011).

Yield parameters

Tuber number per plant

There was significant (P<0.05) influence of potassium (K) rates on tuber number per plant (Table 2). Numerically, the highest (7.76) tuber number per plant was recorded from 150 Kg Potassium (K) followed by 100 Kg K treatment (7.17) (Table 2). The lowest tuber number (6.61) was obtained from control treatment (Table 2). The current study shown that as application of increases the current study revealed the findings of Niguse *et al.* (2016), which indicated the number of tubers per plant gradually increased as the effect of K application rate increased. Moreover, the highest number of tubers per plant was recorded at

150 Kg K2O/ha of K fertilizer application. Number of tubers per plant had shown gradual and significant (P<0.001) increase within increasing K levels (Daniel and Biniam, 2016). Potassium facilitates the translocation of assimilates to the tubers, which ultimately increases the bulking capacity of the tuber and its biomass (Salim *et al.,* 2014).

Average tuber weight

The analysis of variance result indicated that the potassium (K) treatments were significantly (P<0.05) influenced average tuber weight (Table 2). The present study showed the fact that an increase in levels potassium (K) application result in an increase in average tuber weight of potato tubers. This is due to the reason that Potassium (K) improves the growth and development and, increase sizes of each potato tubers. According to Bansal1 and Trehan (2011) Potassium increases the size of tubers, and it increases the yield by increasing the number and yield of large sized tubers. Potassium application exhibited high significant increases of average tuber weight compared to control treatment (Salim *et al.,* 2014).

Table 2. The effects of different rates of potassium on yield parameters of potato at lambuda.

Treatments	Yield parameters				
K (Kg)	MTY (t/ha)	UMTY (t/ha)	TTY (t/ha)	TN	ATW (g)
0	12.41[cd]	4.81[a]	16.65[cd]	6.61[cd]	50.85[d]
50	12.88[c]	3.86[b]	16.69[bc]	6.63[bc]	52.00[c]
100	15.08[ab]	2.56[c]	17.99[ab]	7.17[ab]	54.92[b]
150	15.13[a]	2.24[cd]	18.64[a]	7.76[a]	62.94[a]
CV (%)	13.2	13.7	12.2	8.5	2.1
LSD (5%)	3.15	0.96	3.78	0.91	1.77

Means with the same letter (s) with in a column of a variable were not significantly different at (P < 0.05). CV=Coefficient of variation and LSD=Least significance difference.

Marketable tuber yield

The application of potassium fertilizer significantly (P<0.05) influenced marketable tuber yield (Table 2). Numerically the highest (15.13 t/ha) marketable tuber yield was obtained from 150 Kg of KCl. This is statistically similar with the result of 15.08 t/ha which was obtained with application 100 Kg KCl. The lowest marketable tuber yield (12.41 t/ha) was obtained from control treatment. The present study indicated that the application of potassium (K) produces high marketable tuber yields. This is due to the fact that high K2O application facilitates the translocation of assimilates to the tubers and improves the size tubers. KCl applications increased marketable tuber yield by 38% compared with the control (Salim *et al.,* 2014). Marketable tuber yield increased quadratically with increasing K application rates up to 150 kg KCl ha^{-1} (Karam*et al.,* 2011). Potassium application increased total and marketable tuber yield of potato in comparison to the control (Ajalli*et al.,* 2013).

Unmarketable tuber yield

The analysis of variance indicated that unmarketable tuber yield was significantly (P<0.05) affected by application of KCl (Table 2). The highest unmarketable tuber yield (4.81 t/ha) was recorded from control treatment followed by (3.86 t/ha) from 50 Kg KCl. The smallest (2.24 t/ha) unmarketable tuber yield was obtained from application of 150 Kg KCl (Table 2).

In the present study, as KCl rate increases up to 150 Kg ha^{-1} the unmarketable tuber yield decreased. This is actually describes the fact that KCl improves the tuber sizes.

The treatment application of 150 kg ha^{-1} decreased the unmarkatable tuber yield of potato by more over the control (Haile and Boke, 2011). K helps the potato tubers to attain large size and heavier weight (Karam *et al.,* 2011).

Total tuber yield

The analysis of variance indicated that the K application ($P<0.05$) interaction had significant effect on total tuber yield (Table 2). Numerically, the highest total tuber yield (18.64 t/ha) was recorded from 150 Kg KCl followed by 17.99 t/ha which obtained from 100 Kg KCl. The lowest total tuber yield (16.68 t/ha) was obtained from control treatment (Table 2).The total tuber yield in the present study indicates that at high application of KCl there was high production of total tuber yield (Table 2). This shows that at high application of KCl there might be a production of high number of tubers per plant, which results in high tuber yield. The progressive application of potassium fertilizer from 0 to 225 kg KCl ha^{-1} significantly affected the yield of potato (Karam *et al.,* 2011). The application of potassium fertilizers to the potato crop accelerates plant growth and increases tuber yield (Salim *et al.,* 2014).

Table 3. The Effects of different rates of potassium on quality related parameters of potato at Lambuda.

Treatments		Quality parameters		
	K (Kg)	LT (t/ha)	MT (t/ha)	ST (t/ha)
	0	6.61^{cd}	2.03^{c}	2.38^{a}
	50	6.80^{bc}	2.62^{d}	2.31^{ab}
	100	6.90^{b}	2.92^{ab}	2.18^{abc}
	150	10.95^{a}	3.13^{a}	2.16^{abcd}
CV (%)		13.0	22.0	14.9
LSD (5%)		1.47	1.46	0.87

Means with the same letter (s) with in a column of a variable were not significantly different at ($P < 0.05$). CV=Coefficient of variation and LSD=Least significance difference.

Quality parameters

Fresh tuber size categories

The application of different rates of potassium had in-significantly affected mean yield of small sized tuber. Numerically, as the KCl fertilizer rate increased, the small size categories of tuber were decreased (Table 3). The result indicated that 150 Kg KCl produced relatively less mean yield of small sized tubers and the control treatment produced relatively high figure.

The application of different rates of potassium had significantly affected mean yield of medium sized tuber. Numerically, as the KCl fertilizer rate increased, the medium size categories of tuber were increased (Table 3). The result indicated that 100 and 150 Kg KCl produced relatively higher mean yield of medium sized tubers and the control treatment produced relatively lower figure.

Similarly, the application of different rates of potassium had significantly affected mean yield of large sized tuber. Numerically, as the KCl fertilizer rate increased, the large size categories of tuber were increased (Table 3). The result indicated that 150 Kg KCl produced higher mean yield of large sized tubers and the control treatment produced relatively lower large sized tubers.

Results of many experiments indicated that potassium nutrition influences tuber size. Potassium application increases the size of tubers, especially, if K supply of the soil is low to medium.

Larger tubers are preferred by the processing industry, thus the profitability for the potato grower would be higher (Bansal and Trehan, 2011).

Dry matter content

The analysis of variance indicated that dry matter content was significantly ($P<0.05$) affected by different rates of Potassium (KCl) (Table 4). The highest dry matter content (19.98%) obtained with application of 100 Kg KCl followed by (19.77%) resulted from 150 Kg KCl, while the lowest (17.05%)

was recorded from control treatment (Table 4). The result indicated that the application KCl fertilizer improves the dry matter content of potato tuber. The dry matter content observed in present study revealed the fact that the potato production by potassium fertilizer had high dry matter content. High dry matter content improves the quality of potatoes designated for human nutrition (Manolov *et al.,* 2015). K application improved the dry matter content of tubers, which is highly essential for processing into chips and fries (Bansal and Trehan, 2011). In contrary to the current study, the effect of K was non-significantly increased the dry matter content of potato tuber (Niguse *et al.,* 2016).

Table 4. The effects of different rate of Potassium fertilizer on quality parameters of potato at Lambuda.

Treatments	Quality parameters	
	Dry matter content (%)	Tuber specific gravity (g/cm3)
0	17.05[c]	1.068[c]
50	18.96[b]	1.073[b]
100	19.98[a]	1.077[a]
150	19.77[ab]	1.077[a]
CV (%)	4.6	0.4
LSD(5%)	1.91	0.0031

Means with the same letter (s) with in a column of a variable were not significantly different at ($P < 0.05$). CV=Coefficient of variation and LSD=Least significance difference.

Tuber specific gravity (g/cm3)

The analysis of variance indicated that tuber specific gravity was significantly ($P<0.05$) affected by different rates of Potassium (KCl) (Table 4). The highest (1.077) value of tuber specific gravity was obtained with 100 and 150 Kg of KCl followed by (1.073) obtained by 50 Kg KCl while the lowest (1.068) tuber specific gravity was obtained with control treatment (Table 4). The current study indicated that the application of KCl improves the tuber specific gravity of potato. High specific gravity was acceptable in processing purposes like chips (Elfinesh *et al.,* 2011; Helen *et al.,* 2014).Many studies conducted on the texture of cooked potato tubers have shown the relationship, which exists between texture and specific gravity of raw tubers. Tubers with high specific gravity were noted to have high starch contents and they tend to be mealy in texture and to slough when cooked (Habtam, 2012).

Conclusion

The result from growth parameters of potato indicated that plant height and number of main stems significantly affected by application of different rates of Potassium (K). Accordingly, the higher plant height from 100 Kg KCl (75.09 cm), while shortest plant height was from control treatment (64.23 cm). The higher number of main stems also observed from 100 Kg KCl (7.4) followed by 6.1 from 150 Kg KCl. On the other hand, days to 50% emergence, days to 50% flowering and days to 50% physiological maturity were not influenced by application of different rates of Potassium (K). Similarly, the result from yield parameters clearly indicated highest tuber number per plant was recorded from 150 Kg KCl (7.76) followed by 100 Kg KCl (7.17). The highest average tuber weight was obtained from 150 Kg KCl (62.94 g) followed by 100 Kg KCl (54.92 g). Application of 150 Kg KCl gave highest total tuber yield and marketable tuber yield.

Recommendation

The overall result of the study showed that the application of different rates of Potassium (K) significantly influenced yield and quality of potato tuber at Hadiya (Lambuda area). The higher rates have showed superior performance in most growth, yield and quality parameters. However, since this study was conducted in single season and on single location with application of Potassium (K), it is advisable to repeat the study in multi-locations with more seasons to reach on conclusive recommendation. In future further study on other agronomic practices of the crop is required in the study area. It appears to be worthy of conducting in-depth study on the impact of the factors on potato yield and quality during the off-season in the study area.

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Conflict of interest declaration

The authors have declared that no conflict of interest exists.

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