Effect of Potassium Fertilization Rate on Several Vegetative and Yield Characters of Potato (*Solanum Tuberosum* L.), Grown under Two Different Agro-climatic Regions of Kosovo

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Abstract

The study on the effects of different potassium fertilizer rates on several vegetative and productive characters of potato (*Solanum Tuberosum* L) was conducted during two consecutive years, 2012-2013, in two different agro-climatic regions of Kosovo: Arbnesh Farm of Kosovo Agriculture Institute in Peja (Dukagjini Plain) and in Pestova (Kosovo Plain). Class A seeds with dimensions 35-45 mm of Agria cultivar imported from Netherland were used for planting. A randomized complete block design (RCBD) with four replications and five variants (five levels of potassium, K_2SO_4), consisting on 0, 60, 120, 140, 160 kg ha^{-1} active matter K^+), with a plot size of 240 m^2 (or 12 m^2 for each variant) was used in both locations. Plants were observed throughout the growing period. There was found that the increase of the potassium rate accompanied with the increase of the potato yield and starch content on both locations. Based on the study yield results in both locations, the best recommended rate of potassium fertilizer was from 140 to 160 kg ha^{-1} active matter K^+.

KEYWORDS: Agria, cultivar, fertilizer, K_2SO_4, potassium rate, potato, starch content, yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a very important annual plant which belongs to Solanaceae Family, which is grown from its tubers which are rich in starch and other nutritional substances. The main factors for achieving high potato production are soil type, variety, and agro-technology (Abu-Zinada, 2009; Allisson, *et al.*, 2001). Potato marketable yield is a function of total biomass production, the percentage of biomass that is partitioned to the tubers, the moisture content of the tubers and the proportion of tubers that are acceptable to the market, in terms of size and lack of defects (Ewing, 1997). Great opportunities exist to increase potato yield and quality by improving nutrient management. Potato demands high level of soil nutrients due to relative poorly developed and shallow root system in relation to yield (Davenport & Bentley, 2001; Perrenoud, 1983; Bergmann, 1992). Compared with cereal crops, potato produces much more dry matter in a shorter cycle (Imas & Bansal, 1999). This high rate of dry matter production results in large 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 essential. High yields can only be sustained through the application of optimal NPK doses in balanced proportion. According to Perrenoud (1993), a crop yielding 37 t ha^{-1} removes 113 kg N, 45 kg P_2O_5 and 196 kg K_2O per hectare. Fertilization, especially potassium, is considered one of the most important factors affecting the growth and yield of potato. Many researchers recorded an increase of potato tubers yield as a result of increasing the levels of potassium (K) fertilization (Bardhi & Salceni, 2005; El-Gamal, 1985). Such increases in yield of potato tubers was either due to the formation of large size tubers or increasing of the number of tubers per plant or both (Abd El-Latif *et al.*, 2011). Potassium also plays a key role in increasing crop yield and improving the quality of produce (Tisdale *et al*., 2001; Westermann & Tindall, 1998). Its role is well documented in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates and fats, translocation of photosynthetic, enabling their ability to resist pests and diseases. Potato plants require nutrient for enzyme functions and osmotic regulation (cell structure and strength). The nutrient is highly mobile within conductive tissues and aids in the transport of starch and sugars. Potassium is an essential nutrient for all plants and has a major effect upon yield and quality of potatoes (Fetahu *et al.*, 2004), as well as, the general health and vigour of the crop. Potassium is involved in many aspects of the plant physiology (Youssef *et al*., 2007). It activates more than 60 enzyme systems, aids in photosynthesis, favours high energy status, maintains cell turgor, regulates opening of leaf stomata, promotes water uptake, regulates nutrients translocation in plant, favours carbohydrate transport and storage, enhances N uptake and protein synthesis, promotes starch, protein and vitamins synthesis (Westermann et al., 1994; Marschner, 1995). These multiple functions of K in many metabolic processes lead to numerous positive effects of an adequate K nutrition for potato, such as increases yield, increases proportion of marketable tubers, increases tuber size and specific gravity (Al-Moshileh *et al*., 2005; Fetahu et al., 2004; Perrenoud, 1993), decreases internal blackening and hollow heart, decreases mechanical damages to tubers, decreases storage losses, enhances shipping quality and extends shelf life, improves cooking and processing qualities and chips colour, improves resistance to frost and drought, decreases incidence of diseases [late blight *(Phytophtora infestants)*, dry rot *(Fusarium ssp.)*, powdery scab *(Spongospora subterranea)* and early blight *(Alternaria solanii)*, blackspot bruise, etc (Snyder, 2010; Youssef *et al*., 2007; Panique *et al*., 1997; Marschner, 1995), after-cooking darkening, etc (Imas & Bansal, 1999).

Potassium promotes phloem transport of the photosynthesis products (photosynthates) from the leaves (sources) to the site of their use or storage sinks, tubers (Tawifik, 2001). K_2SO_4 usually gives a higher dry matter content and higher starch content than KCl (Snyder, 2010; Perrenoud, 1993).

The potato plant needs potassium from early stage of plant growth because of its positive effect on root growth, therefore K^+ application at planting is needed. It is a common practice to surface broadcast K fertilizer before planting with incorporation into the soil during seedbed preparation (Rusinovsci et al., 2001). Response to fertilizer and rates of applications vary widely with location, climate, and soil type (Panique *et al.*, 1997). The present study was carried out to determine the effect of potassium fertilizer rates on potato yield of cultivar Agria and its components under two different agro-climatic locations in Kosovo.

MATERIAL AND METHODS

The study on the effects of different potassium sulphate doses on several vegetative and productive characters of potato (*Solanum Tuberosum* L.) was conducted during two consecutive years, 2012-2013, in two different agro-climatic regions of Kosovo: Arbnesh Farm of Kosovo Agriculture Institute in Peja (Dukagjini Plain) and in Pestova (Kosovo Plain). A randomized complete block design (RCBD) (Xhuveli & Salillari, 1984) with four replications and five variants (five levels of potassium sulphate (K_2SO_4), consisting on 0, 60, 120, 140, 160 kg ha^{-1} active matter K^+), with a plot size of 240 m^2 (or 12 m^2 for each variant) was used in both locations. Plants were observed throughout the vegetative period. Agria potato cultivar is one of the most used in Kosovo. Class A seeds with dimensions 35-45 mm of Agria potato cultivar, imported from Netherland (AGRICO), were used for planting. Plants were observed throughout the growing period for several vegetative and productive characteristics, such as the extend of vegetative period from planting to harvest (days), plant height (cm), number of stems per plant, yield (kg ha^{-1}), dry matter content (%), and starch content (%). Plant height (cm), the number of shoots per plant and yield (kg ha^{-1}) were determined using a representative sample of 10 plants taken randomly from each variant in each replication. All data were recorded and mean values were calculated. Dry matter content (%) was determined at harvesting at the Lab Factory Pestovë, using an analytic balance PR, type METTELER TOLEDO LC-P 43 (Switzerland), as it was described by AOAC (1990).

Starch content (%) of fresh potatoes was determined in compliance with the official EC Commission Directive 86/174/EEC and Council Directive 96/25/EC using polarimetric method (Paar, 2013; ISI, 2013) with a MCP/200/300/500 tool with 200 mm polarimeter tube with Peltier option, accuracy 0.01^o optical rotation. Starch content (%) was calculated by following formula:

$$\text{Starch content (\%)} = \frac{2000 * (P - P')}{[\alpha]^{20}_{D}}$$

Where:

P = total optical rotation in angular degrees

P’ = optical rotation in angular degrees of the substances soluble in 40% (v/v) ethanol

$[\alpha]^{20}_{D}$ = specific rotation of pure starch at 20^{o}C, measured in a polarimeter with the wavelength of 589 nm (sodium D-live).

Data were statistically analyzed using MSTAT-C (PROC ANOVA function of SAS) and means were compared using least significant differences method (LSD) at a probability level of 5% and 1% (Snedecor & Cochran, 1980; Papakroni, 2001).

RESULTS AND DISCUSSION

Effect of potassium rates (K_2SO_4 doses) on phenology, plant height (cm) and stem number per plant

Phenology. Potassium fertilization did not affect time of emergence, flowering and physiological maturity. In all treatments, the crop emerged at the same time. The treatments did not show difference in days to 50% flowering. Days to 50% physiological maturity were also similar for all treatments.

Potassium rate (K_2SO_4 doses) did not affect the tubers maturity of Agria potato cultivar at both studied regions. Seeds were sown in the same day for all variants

(April 17) and were harvested on September 4 to 9 of both years of the study. Variants 4 and 5 (140 and 160 kg ha^{-1} active matter K^+) were harvested five days earlier than control and other variants, but differences were not statistically confirmed.

Plant height (cm) and stems number per plant were determined using a representative sample of 10 plants taken randomly from each variant in each replication. All data were recorded and mean values were calculated. The highest value of mean plant height (cm) was observed for variant 5 (160 kg ha^{-1} K_2O) and the lowest value was observed for variant 2 (60 kg ha^{-1} K_2O), 71.5 cm and 67.65 cm, respectively, but differences were not significant between variants and regions at $p \leq 0.05$ (Table 1).

Results showed that stem number of the potato was affected by the application of K fertilizer. In all K treatments were observed higher stem number than control, but the stem number did not follow a decreasing or increasing trend with increasing rates of K application. The highest numbers of stems were observed from application of high rates of K fertilizer (140 and 160 kg ha^{-1} K_2O) (5.15), while the lowest stem number were observed for control (0 kg ha^{-1} K_2O) and variant 3 (120 kg ha^{-1} K_2O) (4.45 and 4.85, respectively), but the observed differences were not significant. There were not observed significant differences between regions, as well (Table 1).

Table 1. Effects of different potassium rates on plant height (cm) and stem number of Agria potato cultivar (different letters indicate significant difference at p<0.05).

№	Potassium rates (K^+ active matter)	Plant height (cm)		Mean	Stem number $plant^{-1}$		Mean
		Pestovë	Pejë		Pestovë	Pejë	
1	0 kg ha^{-1} K_2O (control)	70.1	67.3	68.70	4.4	4.5	4.45
2	60 kg ha^{-1} K_2O	68.8	66.5	67.65	4.9	5.0	4.95
3	120 kg ha^{-1} K_2O	69.9	70.4	70.15	4.9	4.8	4.85
4	140 kg ha^{-1} K_2O	70.7	68.8	69.75	5.1	5.2	5.15
5	160 kg ha^{-1} K_2O	72.1	70.9	71.50	5.2	5.1	5.15

Potato tuber yield (kv ha^{-1}). High tuber production is the final objective of potato cultivation. Tubers of each variant at each replication were separately harvested and weighted and was calculated the yield (kv ha^{-1}). The highest tuber yield (446.16 kv ha^{-1}) was obtained from application of 160 kg K ha^{-1} with a raise of 75.61 kv ha^{-1} compare to control, 62 kv ha^{-1} compare to variant 2 (60 kg ha^{-1} K_2O), and 53.48 kv ha^{-1} compare to variant 3 (120 kg ha^{-1} K_2O). These differences between variants were confirmed statistically at $p \leq 0.05$ and $p \leq 0.01$ in both regions of the study. There were observed not significant differences between regions of the study. There was observed a difference in yield of 16.165 kv ha^{-1} between variants 5 (160 kg ha^{-1} K_2O) and 4 (140 kg ha^{-1} K_2O), but this difference was not significant at $p \leq 0.05$ and $p \leq 0.01$. These results were similar to that reported by Ayalew & Beyene (2011), Panique *et al.* (1997), Davenport and Bentley (2001), Tawfik (2001), Abu-Zinada, (2009), etc. The lowest tuber yield (370.55 kv ha^{-1}) was obtained from variant 1 (control), followed by variant 2 (60 kg K ha^{-1}). All potassium rates showed significantly higher tuber yield compare to control (Table 2).

Table 2. Effects of different potassium rates on yield (kv ha^{-1}) of Agria potato cultivar in two different regions in Kosovo (different letters indicate significant difference at $p \leq 0.05$).

№	Potassium rates (K^+ active matter) (A)	Regions (B)		Mean (B)
		Pestovë	Pejë	
1	0 kg ha^{-1} K_2O (control)	368.47 c	372.24 c	370.55
2	60 kg ha^{-1} K_2O	378.56 bc	389.76 bc	384.16
3	120 kg ha^{-1} K_2O	388.64 b	396.72 b	392.68
4	140 kg ha^{-1} K_2O	428.65 a	431.34 a	429.995
5	160 kg ha^{-1} K_2O	445.74 a	446.58 a	446.16
	Mean (A)	400.015	405.328	A x B interaction
LSD	0.01	20.134	21.345	22.352
	0.05	17.354	18.675	19.135

Effect of potassium rates (K_2SO_4 doses) on dry matter content (%)

Dry matter content (%) is a very important character especially for potatoes used in the alimentary industry. Potato chips market prefers high dry matter content, which confers robustness and crispness to the slices, and low reducing sugar content, to avoid dark browned chips. The lowering in the percent of dry matter caused by heavy K applications can eliminate tubers from the potato chips market. Results showed that dry matter content (%) was affected influenced by the application of potassium fertilizer. In all potassium treatments were observed higher DMC (%) than control, but there were not observed significant differences between control and variant 2 (60 kg ha^{-1} K_2O). The highest dry matter content (%) was observed for the highest potassium rate (160 kg ha^{-1} K_2O) with a mean of 21.325%, while the lowest DMC was observed for control (0 kg ha^{-1} K_2O) and variant 2 (60 kg ha^{-1} K_2O), with a mean of 17.837% and 18.137%, respectively. Differences between control and variant 2, as well as between regions, were not significant (Table 3).

Table 3. Effects of different potassium rates on dry matter content (%) of Agria potato cultivar in two different regions in Kosovo (different letters indicate significant difference at $p \leq 0.05$).

№	Potassium rates (K^+ active matter) (A)	Regions (B)		Mean (B)
		Pestovë	Pejë	
1	0 kg ha^{-1} K_2O (control)	17.775 d	17.90 d	17.837
2	60 kg ha^{-1} K_2O	18.275 d	18.00 d	18.137
3	120 kg ha^{-1} K_2O	19.85 c	19.45 c	19.650
4	140 kg ha^{-1} K_2O	20.625 b	20.625 b	20.625
5	160 kg ha^{-1} K_2O	21.675 a	21.127 a	21.325
	Mean (A)	19.640	19.390	A x B interaction
LSD	0.01	0.9188	0.7188	1.4537
	0.05	0.6554	0.5198	1.0477

***Starch content* (%).** Starch content (%) of fresh potatoes is correlated with potato density (ISI, 2013). Increase of potassium rate was in the right correlation with DMC and starch content (%).The highest starch content (%) was observed for the highest potassium rate (160 kg ha^{-1} K_2O) with a mean of 17.013%, while the lowest starch content (%) was observed for control (0 kg ha^{-1} K_2O) and variant 2 (60 kg ha^{-1} K_2O), with a mean of 13.66% and 13.89%, respectively. Differences between control and variant 2, as well as between regions, were not significant (Table 4).

Table 4. Effects of different potassium rates on starch content (%) of Agria potato cultivar in two different regions in Kosovo (different letters indicate significant difference at $p \leq 0.05$).

№	Potassium rates (K^+ active matter) (A)		Regions (B)		Mean (B)
			Pestovë	Pejë	
1	0 kg ha^{-1} K_2O (control)		13.800	13.875	13.663
2	60 kg ha^{-1} K_2O		14.150	13.625	13.887
3	120 kg ha^{-1} K_2O		15.275	14.785	15.075
4	140 kg ha^{-1} K_2O		15.400	15.600	15.500
5	160 kg ha^{-1} K_2O		17.100	16.925	17.013
	Mean (A)		15.075	14.980	A x B interaction
LSD		0.01	0.5410	0.3445	0.7703
		0.05	0.3858	0.2491	0.5570

Potassium is involved in the activation of the enzyme starch synthase which is responsible of the synthesis of starch. Potassium is the most efficient cation stimulating the activity of this enzyme that catalyzes the incorporation of glucose into long-chain starch molecules (Mengel & Kirkby, 1987). Although potassium activates enzymes involved in starch formation, K can reduce starch content through an increased water content in the tubers (Perrenoud, 1993). It is generally agreed that starch content is enhanced by K^+ application, so long as this is to correct K^+ under-nutrition, whilst heavy doses of K^+ may decrease starch content (Tisdale *et al*., 2001).
Potato tuber yield was highly positively correlated with plant height (cm) and stem number (r = 0.78 and r = 0.86, respectively) and positively correlated with potassium fertilization rate. A very strong relationship was also observed between yield (kv ha^{-1}) and dry matter content (%) and starch content (%) (r = 0.96 and r = 0.94, respectively) (Table 5).

Table 5. Correlation between different characters **(**yield, plant height, stem number, dry matter content and starch content) of Agria potato cultivar grown in two different regions in Kosovo

Characters	Yield (kv ha^{-1})	Plant height (cm)	Stem number	DMC (%)	SC (%)
Yield (kv ha^{-1})	1				
Plant height (cm)	0.782757	1			
Stem number	0.860374	0.472276	1		
Dry matter content (%)	0.962658	0.886951	0.804682	1	
Starch content	0.943448	0.925629	0.749426	0.970291	1

CONCLUSIONS

The observed data showed that potassium fertilizer rate significantly affected the yield, dry matter content and starch content of Agria potato cultivar, grown under two different agro-climatic regions of Kosovo. There were observed significant differences between variants (different potassium rates) for potato tuber yield, dry matter content and starch content. The highest mean potato tuber yield was obtained using 160 kg ha^{-1} K_2O by 446.16 kv ha^{-1}, but there was not significant difference with 140 kg ha^{-1} K_2O rate, with a yield of 429.99 kv ha^{-1} . The highest dry matter content and starch content were measured using 160 kg ha^{-1} K_2O by 21.325% and 17.013%, respectively. For two studied regions of Kosovo, was recommended a potassium rate of 140-160 kg ha^{-1} K_2O, since the differences for potato tuber yield of both rates were not significant. Potassium fertilizer rate must be applied according to the use of potato, cooking or alimentary industry.

References

Abd El-Latif, K. M., Osman, E. A. M., Abdullah, R., Abd el Kader, N. (2011) Response of potato plants to potassium fertilizer rates and soil moisture deficit. Advances in Applied Science Research **2**(2): pp. 388-397.

Abu-Zinada, I. A. I. (2009) Potato Response to Potassium and Nitrogen Fertilization Under Gaza Strip Conditions. Journal of Al Azhar University-Gaza (Nat. Sciences) **11**: pp. 15-30.

Al-Moshileh, A. M. , Errebhi, M. A., Motawei, M. I. (2005) Effect of various potassium and nitrogen rates and splitting methods on potato under sandy soil and arid environmental conditions. *Emir. J. Agric. Sci.* **17**(1): pp. 01-09.

Allison, M. F., Flowler, J. H., Allen, E. J. (2001) Response of Potato (*Solanum tuberosum*. L) to Potassium Fertilizers. The Journal of Agricultural Sciences **136**: pp. 407-426.

AOAC (Association of Official Analytical Chemists) (1990) Official methods of analysis of the Association of Official Analytical Chemists, 15th Edition, Washington DC, USA, 101-152.

Ayalew, A., Beyene, Sh. (2011) The influence of Potassium Fertilizer on the Production of Potato (*Solanum tuberosum* L.) at Kembata in Southern Ethiopia. Journal of Biology, Agriculture and Healthcare **1**(1): pp. 1-13.

Bardhi, N., Salceni, A. (2005) Potato Cultivation, 235 p, pp. 75-78.

Bergmann, W. (1992) Nutritional Disorders of Plants. Gustav Fischer Verlag, New York, 512 p: pp. 127-132.

Davenport, J. R., Bentley, E. M. (2001) Does potassium fertilizer form, source, and time of application influence potato yield and quality in Columbia basin. Amer. J. Potato Res. **78**: pp. 311-318.

El-Gamal, A M. (1985) Effect of potassium level on potato yield and quality. J. Agric. Sci.Mansoura Univ. **10**: pp. 1473–1476.

Ewing, E. E. (1997) Potato. In: The Physiology of Vegetable Crops (Ed.: H.C. Wien). CAB International, UK: pp. 295-344.

Fetahu, Sh., Zhitia, O., Kaciu, S., Rusinovci, I., Avdiu, B. (2004) Determination of production capacity of some cultivars of patato. Procceding of the 3rd Balkanic Symposium 6-11 September 2004, Bursa, Turkey: pp. 175-182.

Imas P., Bansal, S. K. (1999) Potassium and Integrated Nutrient Management in Potato. Proceedings of the Global Conference on Potato 6-11 December 1999, New Delhi, India. Available at http://www.ipipotash.org/en/presentn/kinmp.php.

ISI (International Starch Institute). (2013) Determination of Starch in Potatoes according to EU-direction. Available online at www.starch.dk/isi/methods/starchct.html.

Marschner, H. (1995) Mineral Nutrition of Higher Plants. 2nd Ed. Academic Press, London: pp.112-117.

Mengel, K., Kirkby, E. A. (1987) Principles of Plant Nutrition. 4 th Edition. International Potash Institute, Bern, Switzerland: pp. 135-147.

Paar, A. (2013) Determination of Starch Polarimetric Method (MCP 200/300/500).

Available at www.mep.net.au/foodlab/FL_24/FL24_MCP_Starch.pdf.

Panique, E., Kelling, K. A., Schulte, E. E., Hero, D. E., Stevenson, W.R., James, R.V. (1997) Potassium rate and source effects on potato yield, quality and disease interaction. Am. Potato J. **74**: 379-398.

Papakroni, H. (2001) Used Programs on computer - (2) Excel. Teaching Student's Book, 275 p: pp. 165-175.

Perrenoud, S. (1993) Fertilizing for High Yield Potato. IPI Bulletin 8. 2 nd Edition. International Potash Institute, Basel, Switzerland: pp. 67-77.

Rusinovci, Y., Salillari, A., Pudja, A., Gjeta, Z. (2001) Potato and its cultivation, 230 p: pp. 178-182.

Snedecor, G. W., Cochran, W. G. (1980) One way classification-Analysis of Variance – The random effect model- Two way Classification (Eds) In Statistical Methods. Iowa State Univ. Press, Iowa USA: 215-273.

Snyder, S. (2010) Potassium and Potatoes. Western Farm Press, Timely Reliable Information for Western Agriculture. http://westernfarmpress.com/vegetables/potassium-and- potatoes.

Tawfik, A. A. (2001) Potassium and calcium nutrition improves potato production in drip- irrigated sandy soil. *African Crop Sci. J*. **9**: pp. 147-155.

Tisdale, S. L., Nelson, W. L., Beaton, J. D. (2001) Soil Fertility and Fertilizers. Macmillan Pub. Co., New York, pp: 249-291.

Xhuveli, L., Salillari, A. (1984). Basis of Scientific Experimentation in Agriculture, 329 p: pp. 160-173.

Westermann, D. T., Tindall, T. A., James, D. W., Hurst, R. L. (1994) Nitrogen and potassium fertilization of potatoes: yield and specific gravity. American Potato Journal **71**(7): pp. 417-431.

Westermann, D. T., Tindall, T. A. (1998) Potassium Fertilization of Russet Burbank Potatoes. Better Crops **82**(2): pp. 8-12.

Youssef, Y. A. A., El-Maziny, M. Y., Abdalla, S. A., Meleha, M. E., Hassan, A. A. (2007) Effect of water stress and potassium fertilization on yield quantity and quality of potato. African Crop Science Conference Proceedings, **8**: pp. 445-455.