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Potassium fertilizer rate and source influence content, uptake and allocation of nitrogen, phosphorus and potassium in potato plants

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Abstract
The influence of potassium fertilizer source and rates on the content and the uptake of nutrient elements by potato plant parts from soil were studied. The field experiment included two fertilizer rates - 100 and 200 kg K_2O ha^{-1} supplied as K_2SO_4 or KCl. Increased content of nitrogen in roots at variants fertilized with KCl was observed - 3.01 % for $KCl_{(100)}$ and 3.13 % for $KCl_{(200).}$ Potassium fertilization increased K content in roots compared to control. The N content in aboveground biomass was the lowest for $KCl_{(100)}$ (4.13 %) and for $KCl_{(200)}$ (3.84 %). The applied potassium fertilizers increased K content in aboveground biomass compared to control. The high KCl rate at variant $KCl_{(200)}$ increased K content in aboveground biomass up to 5.16 %. The fertilization with K_2SO_4 led to slight decrease of N content in the tubers compared to control (2.32 %), but he KCl increased tuber N content from 2.60 % at variant $KCl_{(100)}$ to 2.89 % at $KCl_{(200)}$. The K content in tubers was not considerably influenced by the fertilization but an exception was observed for variant $KCl_{(200)}$ where it (2.70 %) exceeded the one at the other variants. Potassium fertilization did not influence P content in plant parts. The highest levels uptaken nutrients were found in aboveground biomass - 50 % of N, 55 % of P and 57 % of K. The tubers contained around 39 % N, 16 % P and 38 % K. Lower levels absorbed nutrients (11 % N, 29 % P and 5 % K) in roots were established.

Key words: Potatoes, potassium fertilization, content and uptake of NPK

1 Introduction

Potato (*Solanum tuberosum* L.) is one of the more often grown crops. Their tubers are a good source of carbohydrates, proteins, vitamins, and minerals in human nutrition (Blagoeva et al., 2004). Potato plants require high quantities of nutrients in soil. For optimum development and high yields they need nitrogen, phosphorus, potassium, calcium, magnesium and various micronutrients (Bogatsevska et al., 2008). The quality of potato tubers and their chemical composition are influenced by many factors - genetics, soil fertility, weather conditions and applied chemical treatments (Rytel et al. 2013). Nitrogen fertilization increases tuber and dry matter yield and the nitrogen content in potato plants (Sharifi et al., 2007; Neshev et al, 2014). According to Bergmann (1992), the content of nitrogen in potato leaves during the early bloom is in the range from 5.00 to 6.50 %. Phosphorus is involved in a wide range of plant processes including development of roots and enhancement of crop maturity (Singh and Rai, 2011). According to Neykova-Bocheva (1988) the content of phosphorus in potato leaves varies between 0.10 and 0.20 %, but for normal development, the optimal content of phosphorus in leaves is from 0.40 to 0.60 % (Bergmann, 1992). Potassium is absolutely necessary element for potatoes. When potassium deficiency is observed the plants are short, leaves become pale-green and later in the vegetation at leaves ends and tops they become necrotic (Kerin and Berova, 2008; Kumar and Sharma, 2013). Potassium deficiency is found when the content in leaves is below 1.00 %. According to Bergmann (1992), optimal content of potassium in potato leaves is from 5.00 to 6.60 %.

The aim of the study was to establish the influence of the rate of potassium fertilization and the potassium source on the content and uptake of nitrogen, phosphorus and potassium in the different plant parts of potatoes.

2 Material and methods

The study was performed during the potatoes vegetation season in 2015. The field experiment was conducted on shallow brown forest soil (Cambisols–coarse) in mountainous region under non irrigated conditions with the variety „Agria”. Randomized block design in 4 replications was used. The size of individual harvesting plot was 16 m^2. Potatoes were planted at the end of May (28^{th}). The harvest was done at the end of September (30^{th}). The experiment included control and two rates of the potassium fertilizers providing 100 and 200 kg K_2O ha^{-1} as K_2SO_4 or KCl. The same rates of nitrogen (as NH_4NO_3) and phosphorus (as triple superphosphate) fertilizers were applied to provide 140 kg N and 80 kg P_2O_5 ha^{-1}, respectively to all the variants including the control. Potato planting distance was 25 x 70 cm. The soil $pH_{(H2O)}$ was 5.44 and it contained 33.9 mg N_{min} kg^{-1}, 32.9 mg P_2O_5 100 g^{-1} and 23.5 mg K_2O 100 g^{-1} before the beginning of the study.
To calculate the content and uptake of nutrient elements, whole plants were analyzed at the end of the vegetation. The samples were dried at 60 ^{o}C, weighted and milled. They were mineralized with concentrated H_2SO_4 using H_2O_2 as a catalyst. The total nitrogen content was determined according to Kjeldahl method by distillation on apparatus Parnas-Wagner (Tomov et al., 2009). The total phosphorus and potassium were established colorimetrically (spectrophotometer model Camspec M105) and photometrically (flame photometer PFP-7), respectively (Tomov et al., 2009). Statistical analysis of collected data for the nutrient content was performed by using Duncan's multiple range test (1955) of SPSS program. Statistical differences were considered significant at $p<0.05$.

3 Results and discussions

Increased content of nitrogen in the roots at variants fertilized with KCl was observed - 3.01% for $KCl_{(100)}$ and 3.13 % for $KCl_{(200)}$ (Table 1). Statistical differences were proved according to Duncan's multiple range test. Potassium fertilization increased potassium content in roots compared to the control. The increase was more pronounced at variants fertilized with KCl (Table 1). Application of K_2SO_4 did not influence nitrogen content in aboveground biomass compare to control, but the KCl fertilization decreased the nitrogen content. The nitrogen content in these variants was the lowest - 4.13 for $KCl_{(100)}$ and 3.84 for $KCl_{(200)}$ (Table 1). Potassium fertilization (source and rate) increased potassium content in aboveground biomass in comparison to the control variant. The high rate of KCl (200 kg K_2O ha^{-1}) increased K content up to 5.16 % (Table 1). These results were in accordance with our previous study performed with the variety "Picasso" where the high rate of KCl fertilizer increased the potassium content in aboveground biomass considerably (up to 6.54 %) (Neshev and Manolov, 2015).

Table 1: Content of N, P and K in roots, above ground biomass and tubers (%)

Variants	Roots			Aboveground biomass			Tubers		
	N	P	K	N	P	K	N	P	K
Control	2.67 b	0.24 a	0.86 b	4.52 a	0.31 a	3.91 c	2.32 c	0.32 a	1.90 bc
$K_2SO_{4\,(100)}$	2.61 b	0.24 a	0.99 ab	4.49 a	0.31 a	4.35 b	2.02 d	0.31 a	2.03 b
$K_2SO_{4\,(200)}$	2.73 b	0.25 a	0.98 ab	4.59 a	0.32 a	4.41 b	2.12 d	0.31 a	2.06 b
$KCl_{(100)}$	3.01 a	0.25 a	1.09 a	4.13 b	0.32 a	4.48 b	2.60 b	0.31 a	2.05 b
$KCl_{(200)}$	3.13 a	0.25 a	1.21 a	3.84 c	0.31 a	5.16 a	2.89 a	0.33 a	2.70 a

Figures with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$).

Results from trails conducted by different authors show that fertilization with NPK influences the content of nutrient elements in potato tubers (Leszczyński and Lisińska 1988; Naz et al., 2011). The fertilization with K_2SO_4 led to slight decrease of nitrogen content in the tubers (2.02 % for $K_2SO_{4(100)}$ and 2.12 % for $K_2SO_{4(200)}$) compared to the control (2.32 %) (Table 1). The KCl fertilization had the opposite influence and increased tuber nitrogen content from 2.60 % at variant $KCl_{(100)}$ to $KCl_{(200)}$ 2.89 %. The potassium content in tubers was not considerably influenced by the fertilization but an exception was observed for the variant $KCl_{(200)}$ where the content of 2.70 % exceeded the content of the other variants. These results correspond with the data of our experiment where the tuber potassium content was higher at variants with applied high KCl rates (Neshev and Manolov, 2015).
Potassium fertilization (source and rate) did not influence phosphorus content in roots, aboveground biomass and tubers (Table 1).

The amount of nitrogen uptaken from potato plants was almost equal for all treatments in the study except variant $K_2SO_{4(100)}$ where the results were the lowest (49.88 kg ha^{-1}) (Table 2). The uptaken nitrogen at the other variants varied between 54.91 and 54.92 kg ha^{-1} at variants $KCl_{(200)}$ and $K_2SO_{4(200)}$, respectively to 56.72 and 57.81 kg ha^{-1} at the control and variant $KCl_{(100)}$.

The application of K_2SO_4 led to increase of total phosphorus uptake from potatoes, while the KCl fertilization had the opposite effect (Table 2). The plants from variant $K_2SO_{4(200)}$ have uptaken the highest amount of phosphorus - 19.03 kg ha^{-1} (Table 1).

Table 2. Total uptake of N, P and K from the plants (kg ha^{-1})

Variants	N	P	K
Control	56.72	18.09	44.50
$K_2SO_{4(100)}$	49.88	18.25	44.94
$K_2SO_{4(200)}$	54.92	19.03	49.13
$KCl_{(100)}$	57.81	17.30	51.46
$KCl_{(200)}$	54.91	17.55	58.28

Plants fertilized with KCl have uptaken more potassium compared to those fertilized with K_2SO_4 (Figure 3). Plants from variants $KCl_{(100)}$ and $KCl_{(200)}$ have absorbed 51.46 and 58.28 kg ha^{-1} potassium from the soil, respectively. The plants from variants $K_2SO_{4(100)}$ and $K_2SO_{4(200)}$ have assimilated 44.94 and 49.13 kg ha^{-1}. The control plants have uptaken the lowest quantity of potassium - 44.50 kg ha^{-1} (Table 1).

Approximately 50 % of absorbed nitrogen from the soil in the study was located in the aboveground biomass independently of potassium fertilizer source (Figure 1). The rest of the uptaken nitrogen was distributed between roots (11 %) and tubers (39 %). In our previous study the same tendency was recorded. Approximately 74 % of absorbed nitrogen from the soil was allocated in the aboveground biomass (Neshev and Manolov, 2015).

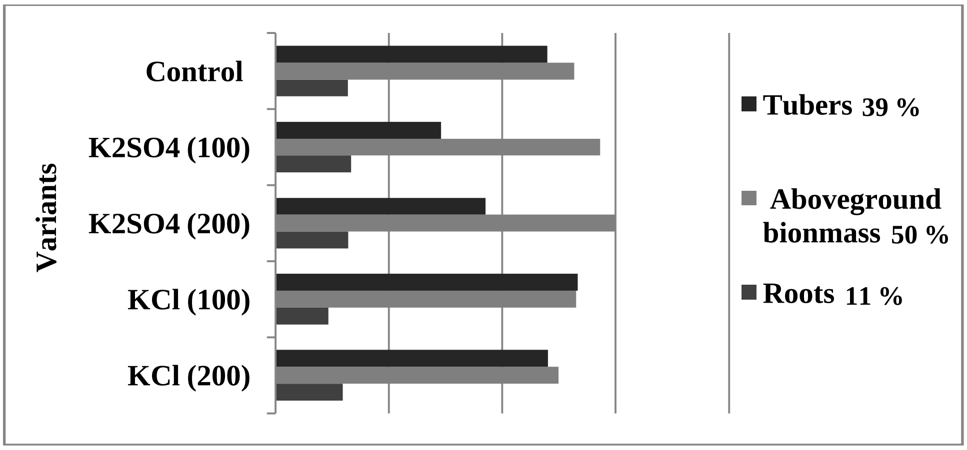

Figure 1. Allocation of N in plant parts

According to Tindall (1991), the uptake of phosphorus from potatoes is relatively lower in comparison with the uptake of potassium and nitrogen. Approximately 55 % of absorbed phosphorus from the soil was allocated in the aboveground biomass (Figure 2). Considerable amount of uptaken P remains in roots about 29 % and the least quantity of the element (16 %) remained in tubers. These results correspond with our previous trail data, where the roots contained about 23 % of the uptaken phosphorus and the quantity of the element in tubers was the lowest - 11 % only (Neshev and Manolov, 2015).

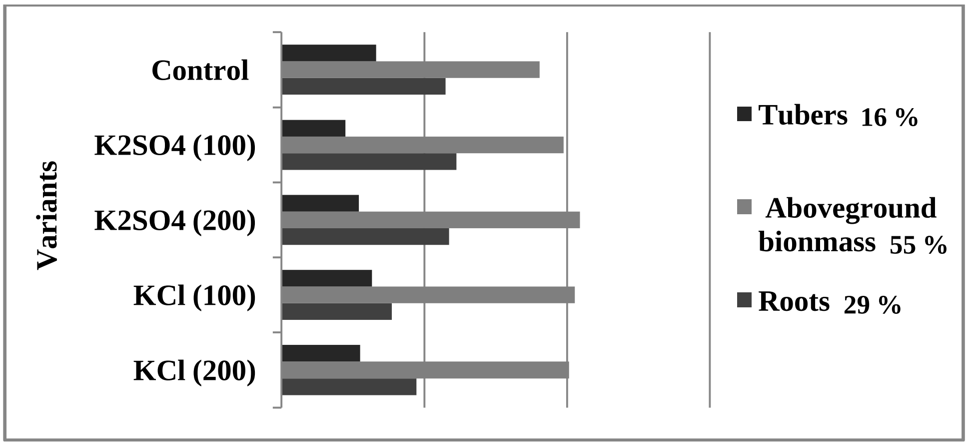

Figure 2. Allocation of P in plant parts

Potatoes uptake more potassium than any other nutrient (Horneck and Rosen, 2008). The highest quantity of K was accumulated in above ground biomass (57 %) followed by tubers (38 %) and roots (5 %). In our studies, performed with the potato variety "Picasso", the highest K amount was accumulated in above ground biomass (Manolov et al., 2014; Neshev and Manolov, 2015).

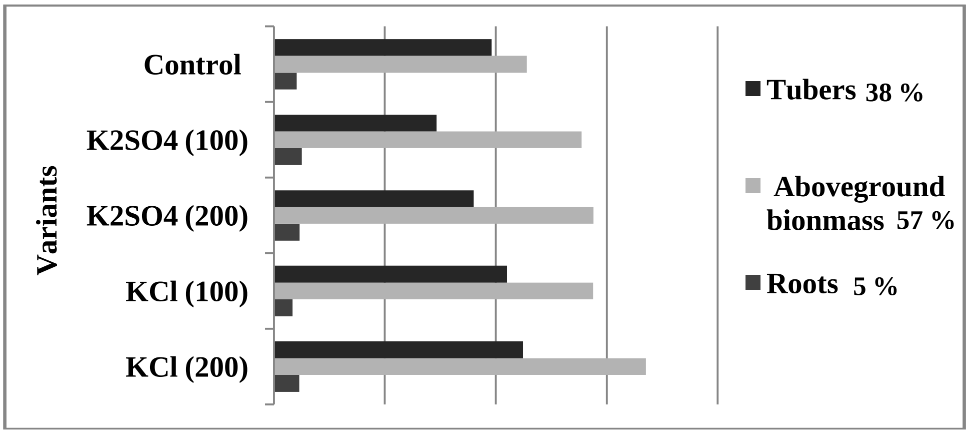

Figure 3. Allocation of K in plant parts

4 Conclusions

Increased content of nitrogen in the roots at variants fertilized with KCl was recorded. Potassium fertilization increased K content in roots compared to the control. The application of KCl decreased N content in aboveground biomass. The K fertilization of potatoes increased the content of the element in the aboveground biomass independently of the K source. The fertilization with K_2SO_4 led to slight decrease of N content in the tubers compared to the control, but the KCl increased tuber N concentration. The K content in tubers was not considerably influenced by the fertilization. An exception was found after application of higher KCl rate (200 kg K_2O ha^{-1}) where the K content in tubers exceeded the concentration of K in other treatments. Potassium fertilization did not influence P content in the plant parts. The amount of nitrogen uptaken from plants was almost equal for all treatments in the study, except variant $K_2SO_{4(100)}$. The application of K_2SO_4 led to increase of total phosphorus uptake from potatoes. Plants fertilized with KCl have uptaken more potassium compared to the other treatments. The highest part of uptaken nutrients were found in aboveground biomass (50 % for N, 55 % for P and 57 for K). The rest of the absorbed nutrients were unequally distributed between the tubers and roots. Considerably high amount of uptaken P (29 %) remained in roots.

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