Content and uptake of nutrients in plant biomass of potato cultivars depending on potassium fertilizer source

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Abstract

The influence of potassium fertilizer source (K_2SO_4 and KCl) at high rate of 600 mg kg^{-1} soil K_2O on content and uptake of nutrients in plant biomass of potato cultivars under pot experimental conditions was studied. Increase of concentration of nitrogen in the roots at application of potassium as KCl for all cultivars was observed (from 3.11 % at "Louisiana" to 3.28 % at "Agria" cultivar) in comparison with the control (2.36 % and 2.30 %) and the variants fertilized with K_2SO_4 (2.25 % and 2.33 %) for both cultivars, respectively . The KCl decreased N content in aboveground biomass compare to the other variants for all cultivars. The potassium fertilization did not influence N and K content in tubers. There was not observed effect of potassium fertilization on phosphorus content in potato plant parts. The highest concentrations of nutrients were found in aboveground biomass (75-83 % of N, 67-73 % of P and 82-85 % of K) followed by tubers (13-20 % of N, 21-25 % of P and 11-21 % of K), and roots (4-5 % of N, 4-6 % of P and 2-5 % of K).

Key words: potatoes, potassium fertilization, content and uptake of N P K

Introduction

Potatoes (*Solanum tuberosum* L.) have the highest botanical and biological diversity among all cultivated plants (Valchev, 2011). Potato crops require large amounts of nutrients and therefore a large amount of fertilizers are applied for their production (Luz et al., 2013). Potassium and nitrogen fertilization is required for maximum potato production. Nitrogen fertilization increases tuber and dry matter yield and the nitrogen content in potato plants (Sharifi et al., 2007; Neshev et al., 2014). The content of nitrogen in leaves of potato plans varies from 5.00 to 6.50 % during the blooming period (Bergmann, 1992). Approximately 74 % of absorbed nitrogen from the soil is alocated in the above ground biomass. The rest of the nitrogen is distributed between roots (14 %) and tubers (12 %) (Manolov et al., 2014). The content of N lower than 2.2 % in leaves lead to decreased yields (Porter and Sisson, 1991). According to Tindall (1991), the uptake of phosphorus from potatoes is relatively lower in comparison with the uptake of potassium and nitrogen. The optimal content of this nutrient in potato leaves is from 0.40 to 0.60 % (Bergmann, 1992). The source of potassium (KCl, K_2SO_4) affects yield and quality of potatoes (Berger et al., 1961; Manolov et al., 2015). It is typical for potatoes to uptake more potassium than any other nutrient element (Horneck and Rosen, 2008). Potassium deficiency is observed when the concentration of the element in potato leaves is lower than 1.0 % (Kerin and Berova, 2008). The increasing potassium fertilizer rates lead to increased content of potassium, sulfur, manganese and zinc in leaves, but decreases the content of calcium and magnesium (Reis and Monnerat, 2000). The biggest part of uptaken potassium is unequally distributed in potato plant parts as the highest K amount is acumulated in above ground biomass followed by tubers and roots (Manolov et al., 2014; Neshev and Manolov, 2015).

The aim of the study was to determine the influence of the source of potassium fertilizer at high rate on the uptake of N, P and K and their allocation in the plant parts.

Proceedings . 51st Croatian and 11th International Symposium on Agriculture. Opatija. Croatia (238-242)

Materials and methods

Experiments were performed with four potato cultivars ("Louisiana", "Riviera", "Husar" and "Agria"). Plants were grown in 15-liter pots containing 15 kg soil with pH (H_2O) 5.67. The soil contained 24.4 mg kg^{-1} mineral nitrogen, 35.2 mg P_2O_5 100 g^{-1} and 43.9 mg K_2O 100 g^{-1} before the beginning of the experiment. The trail was designed to evaluate the cultivars responsiveness to zero potassium fertilization (K_0) and high rate of potassium fertilizer (600 mg K_2O kg^{-1} soil) supplied either as K_2SO_4 or KCl. Ammonium nitrate and triple superphosphate were added to all variants to provide 200 mg/kg^{-1} soil N and 150 mg kg^{-1} soil P_2O_5 respectively. All treatments were replicated 4 times.

To calculate the content and uptake of nutrient elements, whole plants were analyzed at the end of the vegetation. The plant samples were dried at 60 °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 in apparatus of Parnas-Wagner (Tomov et al., 2009). Phosphorus was determined colorimetrically (spectrophotometer Camspec M105) (Tomov et al., 2009) and potassium photometrically (flame photometer PFP-7) (Tomov et al., 2009).

For statistical analyses of collected data, Duncan's multiple range test (1955) of SPSS program was used. Statistical differences were considered significant at $p < 0.05$.

Result and discussion

Increase of concentration of nitrogen in the roots at rate of 600 mg/KCl for all cultivars was observed (3.11 %, "Louisiana"; 3.24 %, "Riviera"; 3.14 %, "Husar" and 3.28 %, "Agria") compared with the other variants (Table 1). Potassium fertilization increased potassium content in roots compare to the control. The increase was more pronounced at variants fertilized by KCl rate (Table 1). The nitrogen content in aboveground biomass for the control and variants fertilized with K_2SO_4 at all cultivars is higher compared with the variants fertilized with KCl (Table 1). This is in accordance with our previous study performed with the cultivar "Picasso". The highest KCl rates (K_{400} and K_{600}) decreased N content in aboveground biomass considerably (Neshev and Manolov, 2015).

Potassium fertilization had a significant influence on K content in aboveground biomass in comparison with the control plants for all studied cultivars. The rates of KCl increased K content approximately with 1 % compared to other treatments from 5.10 % for "Louisiana" to 6.10 for "Agria" (Table 1).

Table 1. Content of N, P and K in potato plant parts

K level	K source	N	P	K	N	P	K	N	P	K
Cultivar Louisiana			Roots			Aboveground biomass			Tubers	
K_0	Control	2.36 b	0.21 a	0.78 b	4.17 a	0.43 a	4.04 c	1.96 b	0.33 a	2.27 b
K_{600}	K_2SO_4	2.25 b	0.21 a	1.02 a	4.20 a	0.42 a	4.59 b	2.20 a	0.32 a	2.38 ab
K_{600}	KCl	3.11 a	0.23 a	1.15 a	3.45 b	0.45 a	5.10 a	2.32 a	0.34 a	2.59 a
Cultivar Riviera			Roots			Aboveground biomass			Tubers	
K_0	Control	2.35 b	0.29 a	2.63 c	4.22 a	0.36 a	4.47 c	2.44 a	0.33 a	2.40 a
K_{400}	K_2SO_4	2.30 b	0.29 a	3.05 b	4.16 a	0.36 a	5.09 b	2.03 b	0.34 a	2.43 a
K_{600}	KCl	3.24 a	0.30 a	3.22 a	3.06 b	0.37 a	5.91 a	2.66 a	0.36 a	2.49 a
Cultivar Husar			Roots			Aboveground biomass			Tubers	
K_0	Control	2.36 b	0.26 a	2.69 b	4.31 a	0.33 a	4.45 b	1.98 b	0.34 a	1.98 b
K_{400}	K_2SO_4	2.35 b	0.26 a	3.25 a	4.40 a	0.33 a	4.76 b	2.19 ab	0.34 a	2.32 ab
K_{600}	KCl	3.14 a	0.27 a	3.58 a	3.38 b	0.35 a	5.56 a	2.60 a	0.34 a	2.68 a
Cultivar Agria			Roots			Aboveground biomass			Tubers	
K_0	Control	2.30 b	0.33 a	2.89 b	4.53 a	0.29 a	4.26 c	2.16 a	0.34 a	1.95 b
K_{400}	K_2SO_4	2.33 b	0.32 a	3.07 b	4.22 a	0.29 a	4.87 b	2.05 ab	0.34 a	2.45 ab
K_{600}	KCl	3.28 a	0.35 a	4.02 a	2.87 b	0.32 a	6.10 a	2.33 a	0.35 a	2.77 a

Figures with different letters are with proved difference according to Duncan's multiple range test ($p < 0,05$).

The studied high potassium rate applied as K_2SO_4 did not influence K content in tubers but the KCl fertilization led to slight increase of K content in these plant parts when compared to control (Table 1).

Potassium fertilization did not influence phosphorus content in roots, aboveground biomass and tubers at the studied cultivars and the content is almost the same for every variant (Table 1). That corresponds with our previous results where the potassium fertilization and the form of the fertilizer did not influence the content of phosphorus in the studied plant parts (Neshev and Manolov, 2015).

Approximately 75 % (cultivar "Riviera") to 83 % (cultivar "Agria") of absorbed nitrogen from the soil was allocated in the aboveground biomass independently of both K sources. (Figure 1). The rest of the uptaken nitrogen was distributed between roots (4-5 %) and tubers (from 13 % for cultivar "Agria" to 20 % cultivar "Riviera). The plants fertilized with the high K_2SO_4 rate have uptaken higher quantities of N compared to those fertilized with KCl (Figure 1). An exception was observed only for cultivar "Agria" where the variant fertilized with KCl have uptaken higher quantities of nitrogen.

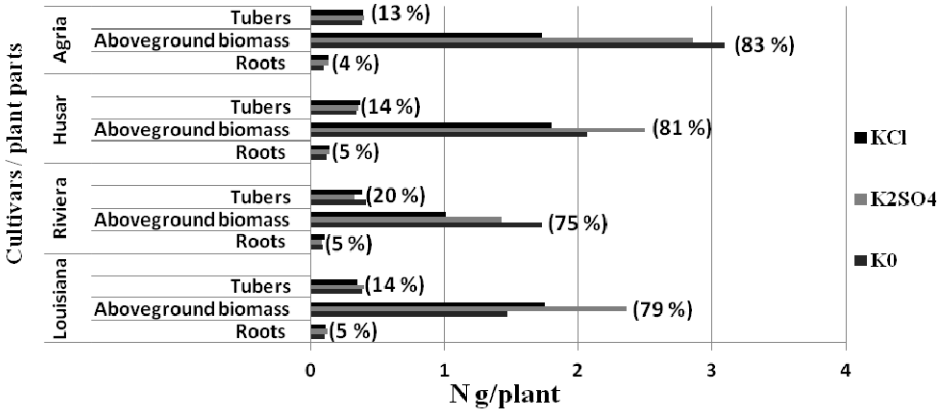

Figure 1. Uptake and allocation of nitrogen among plants' parts

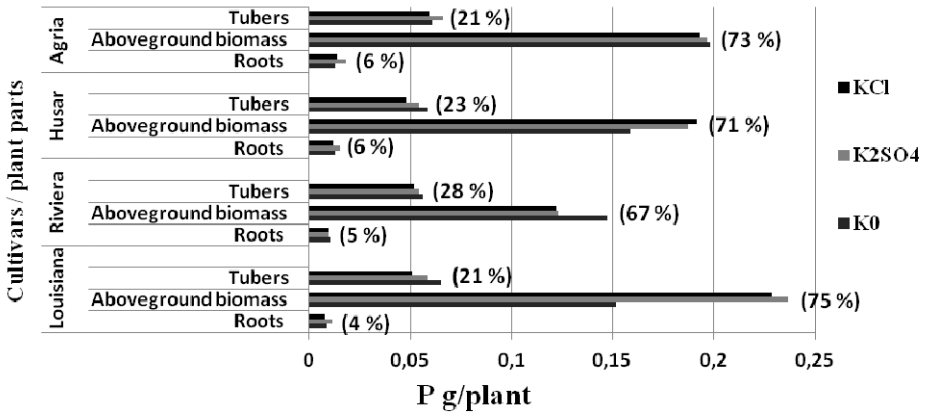

Figure 2. Uptake and allocation of phosphorus among plants' parts

Approximately 67 % (cultivar "Riviera") to 73 % (cultivar "Agria") of absorbed phosphorus was located in the above ground biomass (Figure 2). Roots contained about 4-6 % of the uptaken phosphorus and the rest of the element was accumulated in tubers (21-28 % depending on the cultivar). There was no considerable difference in absorption of phosphorus among plants fertilized with both K sources.

Potato plants uptake more potassium than any other nutrient (Horneck and Rosen, 2008). The highest K amount was accumulated in above ground biomass (from 82 %, cultivar "Louisiana" to 85 %, cultivar "Agria"). The roots contained from 2 % (cultivar "Louisiana") to 5 % (cultivar "Agria"). The rest of the potassium was accumulated in tubers (from 11 % for cultivar "Agria" to 21 % for cultivar "Louisiana").

Plants fertilized with KCl gain more potassium in aboveground biomass compared to those fertilized with K_2SO_4 (Figure 3).

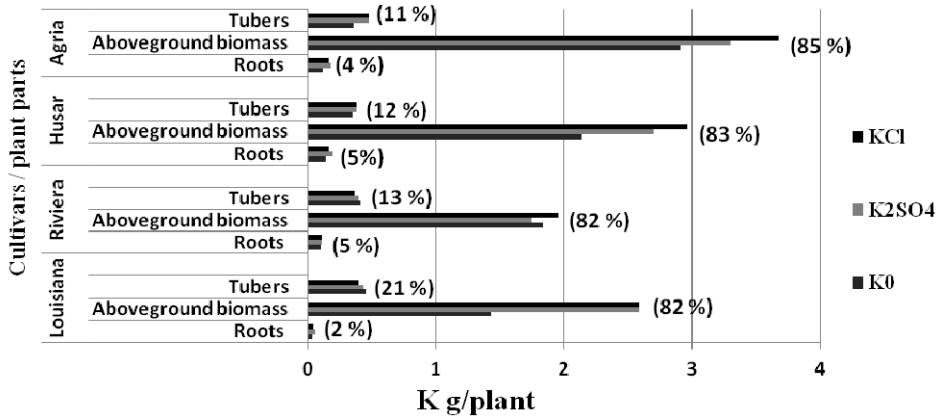

Figure 3. Uptake and allocation of potassium among plants' parts

Conclusions

Increase of concentration of nitrogen in the roots at rates of 600 mg/KCl for all cultivars was observed. High potassium fertilizer rate applied as K_2SO_4 led to slight decreasing of N content in roots. High rate of KCl decreased N content in aboveground biomass at all cultivars. The studied high K rate applied as K_2SO_4 did not influence K content in tubers but the KCl fertilization led to slight increase of K content in these plant parts. Potassium fertilization did not influence phosphorus content in the plant parts. For all cultivars the highest amounts of nutrients were accumulated in aboveground biomass (75-83 % of N, 67-73 % of P and 82-85 % of K) followed by tubers (13-20 % of N, 21-25 % of P and 11-21 % of K) and roots (4-5 % of N, 4-6 % of P and 2-5 % of K).

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sa2016_p0506