Uptake of Iron, Potassium into Barley Grain

Vplyv racionalizácie pestovateľských systémov na príjem Fe, K do zrna jačmeňa siateho

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Abstract

The influence of applied inorganic nutrients in soil, the method of tillage (conventional and minimalization) on accumulation of Fe and K into the grain of selected varieties of barley was observed. Small-parcel experiments were carried out on fields with size 14 m^2 in three parallels. Four levels of fertilization were done: 1) unfertilized control; 2) $N_{70} + P_{4.36} + K_{16.6}$; 3) $N_{60} + P_{22.7} + K_{36}$; 4) $N_{60} + P_{22.7} + K_{36} + Ca_{25}$. Content of Fe, K in grain of barley was assessed by the method of flame AAS. Content of Fe in dry matter of barley grain in analyzed samples were v interval 34.7 – 109.0 $mg{*}kg^{-1}$ and of potassium 293.1 – 658.9 $mg{*}kg^{-1}$. Application of macro elements (N, P, K) into the soil had on the accumulation of Fe into the barley grain reduction effect (beside KM2084 variety) and contrary, in comparison with control treatment increased influence on uptake of mentioned element in winter varieties (beside variety Malwinta) not dependent on the method of amendments of soil by tillage. The content of potassium in grain probably antagonistically affected the content of other macroelements – nitrogen and phosphorus, but it was obviously hard to define certain interaction of the uptake of mentioned element into the grain of spring barley. Addition of $CaCO_3$ in fertilizers affected with contrary – reducing effect of contents Fe and K in barley grain.

Keywords: barley, fertilization, iron, potassium

Abstrakt

Skúmal sa vplyv aplikovaných anorganických živín v pôde, spôsobu orby (konvenčná a minimalizačná) na akumuláciu Fe a K do zrna vybraných odrôd jačmeňa siateho. Maloparcelové experimenty boli realizované na políčkach veľkosti 14 m^2 v troch opakovaniach. Realizovali sa štyri úrovne hnojenia: 1) kontrolný– nehnojený variant 2) $N_{70} + P_{4.36} + K_{16.6}$, 3) $N_{60} + P_{22.7} + K_{36}$, 4) $N_{60} + P_{22.7} + K_{36} + Ca_{25}$. Obsahy Fe, K v zrne jačmeňa boli boli stanovené metódou plameňovej AAS. Obsah Fe v sušine zrna jačmeňa siateho v analyzovaných vzorkách bol v intervale 34.7 – 109.0 $mg{*}kg^{-1}$ a draslíka 293.1 – 658.9 $mg{*}kg^{-1}$. Aplikácia makroprvkov (N, P, K) do pôdy mala na kumuláciu Fe do zrna jarného jačmeňa siateho redukujúci účinok (okrem odrody KM2084) a naopak, v porovnaní s kontrolným variantom skôr zvyšujúci vplyv na príjem tohto prvku v ozimných odrodách (okrem odrody Malwinta) nezávisle na spôsobe úpravy pôdy orbou. Obsah draslíka v zrne pravdepodobne antagonisticky siateho. Adícia $CaCO_3$ v hnojivách pôsobila s opačným – redukujúcim účinkom na obsahy Fe a K v zrne jačmeňa siateho.

Kľúčové slová: draslík, hnojenie, jačmeň, železo

Detailed abstract

Analyzovali sa aplikácie rôznych dávok hnojív do pôdy, spôsob orby (konvenčná a minimalizačná) na akumuláciu Fe a K do zrna vybraných odrôd jačmeňa siateho. Fe a K v zrne jačmeňa boli mineralizované a ich obsah bol stanovený metódou plameňovej AAS na prístroji VARIAN 240FS. Obsah Fe v sušine zrna jačmeňa siateho v analyzovaných vzorkách bol v intervale 34.7 – 109.0 $mg*kg^{-1}$ a draslíka 293.1 – 658.9 $mg*kg^{-1}$. Odrody ozimného jačmeňa mali v porovnaní s odrodami jarného jačmeňa výrazne nižšie hodnoty príjmu Fe do zrna jačmeňa (okrem odrody Wintmalt, kde bol jeho obsah v ozimnom jačmeni najväčší). V jarnom jačmeni sa nedal jednoznačne určiť vplyv odrody na kumuláciu Fe do zrna; vyšší príjem tohto prvku sa zaznamenal v odrode Xanadu. Najväčší obsah K v zrne ozimného jačmeňa bol zaznamenaný v odrode Malwinta, v jarnom jačmeni mala relatívne najvyšší obsah K v v zrne odroda KM2084. Aplikácia makroprvkov (N, P, K) do pôdy mala na kumuláciu Fe do zrna jarného jačmeňa siateho redukujúci účinok (okrem odrody KM2084) a naopak, v porovnaní s kontrolným variantom skôr zvyšujúci vplyv na príjem tohto prvku v ozimných odrodách (okrem odrody Malwinta) nezávisle na spôsobe úpravy pôdy orbou. Obsah druhého skúmaného prvku nebol prakticky výraznejšie ovplyvňovaný prítomnosťou (ako aj hladinou) dodaných živín (N, P, K) v jačmeni jarnom, v ozimnom jačmeni bol nevýrazný rozdiel len vo vyživovaných variantoch v odrode Malwinta, ich množstvo K v zrne bolo vyššie v porovnaní s kontrolnými variantami v oboch aplikovaných druhoch orby. Adícia $CaCO_3$ v hnojivách skôr znižovala obsah Fe v zrne v skúmaných odrodách jačmeňa siateho.

Introduction

Barley, the world’s fourth most important cereal after wheat, rice and maize suffers huge yield losses due to disease leaf blight that severely affects aerial parts of the plant. Cultivated barley is grown in a range of diverse environments that vary from sub-artic to sub-tropical, with greater concentration in temperate areas and high altitudes of the tropics and subtropics. Barley is increasing in popularity as a food grain and is used in flours for bread making or other specialties such a s baby foods and thickeners. It is preferred by some food manufactures due to its lower price compared to wheat and its nutrional value (Akar, et al., 2004).
Other than the cool highlands, barley is rarely grown in the tropics as it is not situed to warm humid climates (Nevo, 1992). Until the late nineteenth century, all barleys existed as highly heterogeneous landraces adapted to different environments. Over the past 100 years, the landraces have mostly been displaced in agriculture by pureline varieties with reduced genetic diversity (Nevo, 1992). Extensive cultivation, intensive breeding and selection have resulted in thousands of commercial varieties of barley. For commercial purposes, barley varieties are classified into broad classes that are used as a basis for world trade (Abare, 2007).
Iron is important essential micronutrient for both plant and human (Yolcu, et al., 2010). Iron is required for life-sustaining processes from respiration to photosynthesis, where it participates in electron transfer through reversible redox reactions, cycling between Fe^{2+} and Fe . Insufficient Fe uptake leads to Fe-deficiency

Yi, 1994). Although Fe is the fourth most abundant element in the earth's crust, it is not readily available to plants. In well-aerated soils at physiological pH, the concentrations of free Fe^{3+} and Fe^{2+} are less than 10^{-15} mM, a value far below that required for optimal growth (Marschner, 2011). Thus, Fe-deficiency often limits plant growth causing agricultural problems. Iron uptake in plants is highly regulated in order to supply amounts sufficient for optimal growth while preventing excess accumulation (Kim and Louguerinot, 2007).

Potassium is relatively abundant in all living cells and forms an essential part of their physico-chemical structure. In contrast to Na cell walls are very permeable to K ions. Potassium is a vital nutrient for plant growth and development. Plants are able to accumulate substantial tissue contents of K^+, with some estimates of K^+ comprising 10% of plant dry weight, while, subcellularly, K^+ is the most abundant cation in plant cells (Leigh and WynJones, 1984; Very and Sentenac, 2003).

Potassium facilitates many functions in plants, including photosynthesis, enzyme activation, and osmoregulation. It aids in the production of adenosine triphosphate (ATP), which affects the rate of photosynthesis, and acts as a catalyst for over 60 enzymatic processes related to plant growth (Armstrong, 1998).

The objective of our study was to determine the relation of Fe and K accumulation into barley grain in relation to type of tillage (minimalization and conventional) as well as in relation to three different levels of doses of inorganic nutrients.

Materials and methods

This experiment was established in experimental base lands of Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra – Dolná Malanta. This locality is flat, height above sea level is 177 m, coordinates are 48º19' central-west width; 18º09' east-west longitude. The soil was extracted using the Mehlich III method (CH_3COOH, NH_4NO_3, NH_4F, HNO_3 and EDTA). The content of available phosphorus (P) in the extract was determined colorimetrically and the content of available potassium (K) and iron (Fe) by atomic absorption spectrometry (AAS). The ion-selective electrode (ISE) method was used to determine the pH value after extraction in 0.01 M KCl (Table 1). The values of pH/KCl in soil were slightly acidic, the content of nitrogen in soil was medium, the content of phosphorus was sufficient, and the content of potassium and iron is under standard values.

Experiments were based on block method. One variant area was 14 m^2 large. Small-parcel technique was used for seeding, treatment and harvesting. Grown grain crop was sorted out and we took three samples from it.

Table 1 Agrochemical soil properties of research plots in Kolíňany
Tabuľka 1 Agrochemická charakteristika pôdy na výskumných pozemkoch v Kolíňanoch

Soil reaction	Humus content	Nutrients			
		N_{an}	P	K	Fe
(pH/KCl)	(%)	$(mg*kg^{-1})$	$(mg*kg^{-1})$	$(mg*kg^{-1})$	$(mg*kg^{-1})$
6.1	2.97	11.3	64.8	196.0	21612.3

Characteristics of level of fertilization and tillage methods

In this experiment, four levels of fertilization were applied: 1) unfertilized (control variant), 2) fertilization by the fertilizer Condit mineral batched 1 t*ha^{-1} (which added to soil 70 kg N∗ha^{-1}, 4.36 kg P∗ha^{-1} and 16.6 kg K∗ha^{-1}), 3) application of the following fertilizers: Amofos batched in 150 kg, KCl (60 %) 60 kg∗ha^{-1}, Hakofyt 150 dm^3∗ha^{-1} and NH_4NO_3, in total, we added to the soil 60 kg N∗ha^{-1}, 22.7 kg P∗ha^{-1}, 36 kg K∗ha^{-1}, 4) same level of fertilization as in the previous case, however, instead of the last applied separate fertilizer NH_4NO_3 we used mixture of NH_4NO_3 + $CaCO_3$ and so we added 60 kg N∗ha^{-1} and 25 kg Ca∗ha^{-1} to the soil.
We realized two types of tillage: conventional tillage (tillage up to the depth of 0.18 – 0.20 m) and minimalization – disc ploughing (up to the depth of 0.10 – 0.12 m). Three repetitions were carried out in this experiment.

Sampling and preparation of samples

Three species of winter barley were used, exactly: Malwinta, Graciosa, Wintmalt and four species of spring barley: Kangoo, KM2084, Marthe, Xanadu.
Analysis of zinc, copper in tested material after mineralization was realized in two phases (Koppova, et al., 1955):
- in the first phase, 2 g of milled grain of barley is decomposed in dry way while adding of about 0.5 cm^3 of concentrated HNO_3 oxidizer. It was incinerated in sand bath, then it was annealed in muffle furnace at the temperature of 500 – 550 °C.
- in the second phase, after incineration, this material was mixed up with HNO_3 in the rate of 1:3. Then it was rinsed and added in 50 cm^3 volumetric flask after filtration. Finally we set amount of Zn and Cu using AAS method by Varian DUO 240FS/240Z device.
The data were statistically analysed by means of variance analysis (ANOVA) using the statistical programme Statistica.

Results

Minimums and maximums of observed elements uptake more significantly related to varieties of barley (Tab. 2, 3): the lowest content of iron (34.7 mg∗kg^{-1}) and potassium (293.1 mg∗kg^{-1}) was evaluated in dry matter of winter barley in variety Graciosa, contrary the highest content of Fe: 109.0 mg∗kg^{-1} (as well as the second highest content of K: 655.3 mg∗kg^{-1}) in dry matter was evaluated in variety Wintmalt.
After averaging of observed elements amounts in barley grain in all variants of individual varieties (i.e. fertilized with control variant) and after comparison the following line of spring barley varieties was observed by uptake of Fe: Marthe > Kangoo > KM2084 > Xanadu after application of conventional tillage and line of uptake of Fe into grain of barley after application of minimalization tillage was as following: KM2084 > Kangoo > Xanadu > Marthe. By winter varieties the line of average values of all variants was approximately the same abstractedly from the way of tillage as following: Wintmalt > Malwinta >Graciosa. When evaluating average contents of K in barley grain with comparison to spring varieties the following line was observed: Xanadu > Marthe > KM2084 > Kangoo– after application of conventional tillage and by other way of tillage was the line as following: Marthe > Xanadu > Kangoo > KM2084. The line by winter barley varieties was as following: Malwinta > Wintmalt > Graciosa (after application of conventional tillage) after application of minimalization tillage: Malwinta > Graciosa > Wintmalt.

type of tillage and four levels of fertilization (in the table are numerically labeled right subscript): 1) unfertilized control; 2) $N_{70} + P_{4.36} + K_{16.6}$; 3) $N_{60} + P_{22.7} + K_{36}$; 4) $N_{60} + P_{22.7} + K_{36} + Ca_{25}$.).

Tabuľka 2 Obsah železa (mg*kg^{-1}) v zrne v rôznych odrodách jačmeňa siateho v závislosti od druhu aplikovanej orby a od štyroch úrovní hnojenia (v tabuľke sú číselne označené pravým dolným indexom): 1) kontrolný – nehnojený variant; 2) $N_{70} + P_{4.36} + K_{16.6}$; 3) $N_{60} + P_{22.7} + K_{36}$; 4) $N_{60} + P_{22.7} + K_{36} + Ca_{25}$.

Fe	tillage + level of fertilization	Spring barley varieties				Winter barley varieties		
		Marthe	KM2084	Xanadu	Kangoo	Malwinta	Graciosa	Wintmalt
1	conven.$_1$	106.8^{Aa}	53.0^{Ab}	73.3^{Ab}	73.1^{Ab}	46.2^{Aa}	41.7^{Ab}	42.0^{Aa}
2	conven.$_2$	68.5^{Aa}	63.9^{Ba}	71.9^{Bb}	65.6^{Ba}	42.9^{Ba}	44.4^{Aa}	49.3^{Ba}
3	conven.$_3$	65.7^{Aa}	75.5^{Ba}	54.0^{Ba}	65.6^{Bb}	49.8^{Aa}	50.9^{Aa}	54.9^{Cb}
4	conven.$_4$	66.0^{Ba}	68.7^{Ba}	63.8^{Ca}	72.9^{Cb}	43.9^{Ba}	44.2^{Ab}	109.0^{Bc}
5	minimal.$_1$	69.1^{Aa}	67.4^{Aab}	75.9^{Ab}	71.8^{Aa}	70.0^{Aa}	44.3^{Ab}	61.6^{Aab}
6	minimal.$_2$	47.2^{Ba}	79.8^{Bb}	72.6^{Ab}	68.4^{Bb}	57.0^{Aa}	45.4^{Ab}	55.3^{Ba}
7	minimal.$_3$	62.8^{Ba}	98.4^{Ab}	65.5^{Bab}	79.2^{Ac}	44.7^{Aa}	38.3^{Aa}	62.5^{Ab}
8	minimal.$_4$	62.2^{Aa}	70.2^{Ba}	64.7^{ABa}	70.0^{Ca}	42.3^{Ba}	34.7^{Ba}	88.7^{Bb}

Capital letters in table stand for statistical significance in columns (P<0.01) and small letters stand for statistical significance in rows (P<0.01) between varieties of spring barley and winter barley (Their conformity means that the values are statistically non-significant and different letters characterize statistically strong significance).
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The presence of fertilizers in soil has caused reducing of Fe uptake into grain of all barley varieties (besides variety KM2084) and by variety Malwinta (winter barley) in comparison to non-fertilized (control) variants abstractedly from the soil amendment by tillage (statistically highly significant only by variety Kangoo). Higher doses of nitrogen in soil (200 kg.ha^{-1}) in form of urea increased according to Loššák et al. (2011) the contents of iron and zinc in grain of maize (*Zea mays L*.) but only in one year of two experimental years in comparison to variant with applied nitrogen in dose of 120 kg.ha^{-1}

Liming with $CaCO_3$ (in combination with fertilizing) had not effect on Fe uptake into grain of spring barley by variety Marthe (in comparison to previous non-limed variant), in winter barley by variety Wintmalt invoked (statistically highly significant) increased uptake of Fe into grain abstractedly from type of applied tillage. Application of $CaCO_3$ caused increased uptake of Fe into grain also in other spring varieties of barley Xanadu and Kangoo which was statistically significant; in others variants there was decline in iron uptake to barley grain in limed variants, in comparison to non-

Soil amendment by liming caused decline in K level by all winter varieties of barley (statistically highly significant only by variety Wintmalt) in comparison with variants $N_{60.0}$; $P_{22.4}$; $K_{36.0}$, as well as in one variety of spring barley (Kangoo) abstractedly from the type of applied tillage. By spring varieties KM2084 and Xanadu there was also observed decline of K in barley grain, but only after application of minimalization tillage.

Table 3 Content of potassium in grain (mg*kg^{-1}) of different varieties of barley in relation to type of tillage and four levels of fertilization (in the table are numerically labeled right subscript): 1) unfertilized control; 2) N_{70} + $P_{4.36}$ + $K_{16.6}$; 3) N_{60} + $P_{22.7}$ + K_{36}; 4) N_{60} + $P_{22.7}$ + K_{36} + Ca_{25}.

Tabuľka 3 Obsah draslíka (mg*kg^{-1}) v zrne v rôznych odrodách jačmeňa siateho v závislosti od druhu aplikovanej orby a od štyroch úrovní hnojenia (v tabuľke sú číselne označené pravým dolným indexom): 1) kontrolný – nehnojený variant; 2) N_{70} + $P_{4.36}$ + $K_{16.6}$; 3) N_{60} + $P_{22.7}$ + K_{36}; 4) N_{60} + $P_{22.7}$ + K_{36} + Ca_{25}.

K		Spring barley varieties				Winter barley varieties		
	tillage + level of fertilization	Marthe	KM2084	Xanadu	Kangoo	Malwinta	Graciosa	Wintmalt
1	conven.$_1$	612.4^{Aa}	595.0^{Aa}	615.7^{Aa}	592.0^{Ab}	637.1^{Aa}	293.1^{Ab}	647.4^{Aa}
2	conven.$_2$	616.1^{Aa}	596.3^{Ba}	614.5^{Ba}	597.4^{Ba}	650.0^{Aa}	488.6^{Aa}	530.1^{Ba}
3	conven.$_3$	617.9^{ABa}	588.2^{Cb}	615.2^{Cab}	597.0^{Bb}	658.9^{Aa}	524.8^{Aa}	627.7^{Ca}
4	conven.$_4$	584.7^{Ba}	596.8^{Bab}	622.9^{BCb}	589.6^{Bab}	657.6^{Aa}	504.8^{Bab}	602.2^{Ab}
5	minimal.$_1$	620.1^{Aa}	587.5^{Ab}	609.3^{Aab}	594.8^{Aab}	621.2^{Aa}	632.3^{Aa}	629.4^{Aa}
6	minimal.$_2$	617.9^{Ba}	586.9^{Ab}	614.1^{Aa}	598.3^{Ba}	647.5^{Aa}	642.3^{Bb}	612.3^{Bab}
7	minimal.$_3$	615.2^{Ba}	592.7^{Ba}	611.3^{Ba}	600.0^{Aab}	649.7^{Ba}	649.4^{Ca}	655.3^{Aa}
8	minimal.$_4$	622.5^{Aa}	589.5^{Cb}	610.4^{Ca}	589.2^{Ca}	649.8^{Ba}	603.8^{BCa}	486.5^{Cb}

Capital letters in table stand for statistical significance in columns (P<0.01) and small letters stand for statistical significance in rows (P<0.01) between varieties of spring barley and winter barley (Their conformity means that the values are statistically non-significant and different letters characterize statistically strong significance).

Discussion

As Tab. 2 refers, fertilizing with N, P, K had not unique influence on distribution of Fe from soil into plants (with accumulation into the grain of tested variants of barley). Hao, et al. (2007) compared amounts of Fe in grain of brown rice after application 0, 80, 160, 320 kg N*ha^{-1} into soil and found out that the amount of Fe in grain of brown rice was gradually increased in comparison with control by dose of 160 kg N*ha^{-1}, but by dose of 320 kg N*ha^{-1} the amount of Fe began to decline in grain of brown rice. By lowest dose of fertilizing (80 kg N*ha^{-1}) Hao, et al. (2007) did not find by most

kg $N*ha^{-1}$.
In correspondence of such findings is also another result presented by Rongli, et al. (2010), who refered that the concentrations of Fe in the whole grain of winter wheat were greater in the N_{130} and N_{300} treatments than in the control but did not differ between the N_{130} and N_{300} treatments. The contents of Fe were greater in the in the N_{130} and N_{300} treatments than in the control but did not differ between the N_{130} and N_{300} treatments.
Yolcu, et al. (2010) refers that solid and combined manure treatments increased the Fe content of the intercropping mixture while the liquid manure treatments reduced its content. Singh and Dahiya (1980) also reported that farmyard manure application increased Fe concentration up to a definite level and then reduced its content in oat. Increased content of iron in presence of organic fertilizers (as well as in presence low concentration of Cd in plants of sorghum) were interpreted also by Pinto, et al. (2004), as well as Chen, et al. (1998) and Chen, et al. (2000), who published that the presence of organic matter also increased Fe and Zn transport from root to shoot for all levels of Cd in nutrient solution, also observed an enhanced transport of Fe from root to shoot in the presence of humic substances, as well as an increase of Fe solubility in plant tissues.
The combination of fertilizers with macroelements N, P, K with increased doses of nitrogen by Jurkovič, et al. (2006) and Komljenovic, et al. (2006) had not any effect on accumulation of Fe into leaves of maize, so it could be predicted that the combination of these macroelements activates indifferent Fe uptake into vegetative and generative organs of plants. Similar results were achieved also by Yolcu and Turan (2008), who referred in their work that increased doses of nitrogen fertilization (after P applications) reduced Fe content of alfalfa smooth brome grass intercrops ($p < 0.01$). The highest Fe content of the intercrops was obtained at no nitrogen fertilization application treatments (215.58 mg $Fe*ha^{-1}$) and this value was followed by 60 kg $N*ha^{-1}$ (201.25 mg $Fe*ha^{-1}$) and 120 kg $N*ha^{-1}$ (197.71 mg $Fe*ha^{-1}$) fertilization applications. These results are in consistency with works of Sönmez and Yilmaz (2000), who reported that nitrogen fertilization reduced Fe contents of barley grain.
The potassium content of the intercropping mixture (Yolcu, et al., 2010) in cattle manure applications was not significantly different. In other studies, it was reported that manure had no effect on the K of the maize shoot (Iqbal, et al*.,* 2007) and of cereals (Yolcu and Turan, 2008). The linear relationship between forage K content and dairy manure compost application was reported by Butler and Muir (2006).
In our work (Tab. 3) an increased content of K in barley grain was not observed with increasing doses of this macroelements in fertilizers, what could be in normal relation to mentioned parameters awaited, as it is mentioned in work of Çelik, et al. (2010), who put various doses of K and Fe into soil and found out increasing relation of K content in leaves of maize to increased amount of K in fertilizers. Thus it is possible to conclude that the presence of other macroelements in fertilizers together with K involves not unique relation of K uptake into plants. Subtle contrary was found by Maňásek et al. (2011), referring that after application of nitrogen (120 $kg.ha^{-1}$) in combination with K_2O (125$kg.ha^{-1}$) the content of iron was slightly reduced in grain of maize (*Zea mays conv. Saccharata*) in comparison to experimental variant only with applied nitrogen (120 $kg.ha^{-1}$).

Conclusion

Food Codex of Slovak republic does not define maximal acceptable amounts of Fe and K in grain of cereals, thus it is not possible to mention limit values of observed

Wintmalt as wel as potassium by variety Malwinta.

Combination of macroelements (N, P, K) in fertilizers had not clear influence on Fe and K uptake into grain of our tested varieties of barley. There was decline in Fe content by spring varieties of barley, in contrary, when comparing to winter varieties with its slight increase of mentioned element. It could be possible to compare our findings to published works that refer about clear increase of Fe content into grain of plants after application of nitrogen in dose of 150 $kg*ha^{-1}$ in comparison to non-fertilized variants (but not in combination also with increased doses of phosphorus – in our work this fact was confirmed).

Presence of $CaCO_3$ together with fertilizers, had increased influence on reducing of potassium content (besides variety Marthe) always after application of minimalization tillage, in comparison to non-limed variant with the same amount of N, P, K. The applied types of tillage had not significant influence on intake of K into grain of tested varieties of barley.

Acknowledgement: The work was supported by grants VEGA 1/0456/12, VEGA 1/0724/12 and Centre of excellence for white-green biotechnology, ITMS 26220120054, supported by the Research & Development Operational Programme funded by the ERDF.

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