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# CONTENT OF MINERALS IN TUBERS OF POTATO PLANTS TREATED WITH BIOREGULATORS

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## ABSTRACT

**By stimulating life processes in plants, growth regulators enhance the plants' resistance to stress conditions, improve their health and contribute to higher and better quality yields. The purpose of this study has been to analyse the effect of biostimulators on the mineral composition of potato tubers. Four cultivars of edible potato were grown in a field experiment: very early cultivar Volumina and medium early ones Irga, Satina and Sylvana. From the BBCH 39 phase (crop cover complete), potatoes were treated three times, at 10- to 14-day intervals, with the biostimulators Asahi SL, Bio-Algeen S90 and Kelpak SL. Potatoes not treated with any biostimulator served as control. The content of minerals in potato tubers varied, depending on the weather conditions in each season, on the cultivars and on the applied growth stimulators. The concentrations of phosphorus and magnesium in tubers were higher in the first year, whereas the level of potassium was higher (by 22.8%) in the second year of the experiment. The growth stimulator Asahi SL increased the concentration of minerals in tubers, while Bio-Algeen S90 and Kelpak SL decreased their content. A higher concentration of macronutrients was determined in tubers of the cultivars Volumia and Sylvana. Following the transformations which occurred in potato tubers during their storage, their content of mineral components increased.**

**Key words:** potato cultivars, biostimulators, storage, macronutrients.

## INTRODUCTION

The high nutritional and culinary values of potato make it a staple food in the diet of most people in Poland. In 2013, the total acreage cropped with potato was 337,000 ha and the average yield was 21.1 $t \cdot ha^{-1}$ (Statistical Yearbook, 2014). The potato consumption per capita was 102 kg. Potatoes are a source of protein, vitamin C, folic acid, some group B vitamins and minerals (Nutrition Standards, 2012; Robert et al., 2006). Potassium, calcium and magnesium are especially valuable elements in potato tubers, but their consumption also covers some of the organism's demand for phosphorus, iodine and copper.

Prolonged storage of potatoes is the stage at which good quality of tubers is most difficult to maintain, because the transformations occurring at that time lead to quantitative and qualitative changes in the composition of tubers. According to Pobereżny and Wszelaczyńska (2011), the loss of dry matter and starch depends on the duration of a storage period and the fertilisation applied under potato plants.

By stimulating life processes and regulating the mineral balance in plants, growth stimulators enhance the plants' resistance to stress conditions, as a result of which they improve the quality and volume of yields (Wierzbowska et al., 2010). Applied to potato, they affect the yield of tubers, improve their biochemical parameters and increase the plant's tolerance to unfavourable habitat conditions as well as pathogens (Sawicka et al., 2011). Extracts from algae are an inexpensive source of natural growth stimulators and other bioactive substances. Used as biostimulators in agriculture and horticulture, they raise yields and improve the quality of plants (Panda et al., 2012). They can also alleviate the stress due to the shortage of nutrients, which means that lower doses of mineral fertilisers are needed (Papenfus et al., 2013).

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The purpose of this study has been to verify the effect of biostimulators on the mineral composition of potato tubers.

## MATERIAL AND METHODS

The research was based on a field experiment, set up in a random sub-block design and situated at the Research Station in Tomaszkowo, property of the University of Warmia and Mazury in Olsztyn. Potatoes were grown on arable land classified as R IVa, i.e. of medium and better quality, on brown soil which was dystric Cambisol developed from loamy sand. The soil had the following characteristics: pH = 5.32- 5.70 in 1 mol KCl $dm^{-3}$, content of available elements: 69-72 mg P $kg^{-1}$, 82-90 mg K $kg^{-1}$ and 38-48 mg Mg $kg^{-1}$.

Concentrations of available forms of P and K were determined with the Egner-Riehm method (PN-R-04023:1996 and PN-R-04022:1996+Az12002); Mg was determined according to Schachtschabel (PN-R-04020:1994+Az:2004) and the soil pH was measured by potentiometry (ISO 10390:1997).

Four potato cultivars were grown: very early cv. Volumnia and three moderately early varieties Irga, Satina and Sylvana. The preceding crops were cereals (oat in 2011 and winter triticale in 2012). Each year in autumn, the field was nourished with manure 25 t $ha^{-1}$, while in spring the following mineral fertilisation was applied: N – 40 (urea 46% N); P – 60 (superphosphate 17.45% P); K – 100 (potassium salt 50% K) kg $ha^{-1}$. Tubers were planted at the end of April, at 67.5 × 40 cm spacing. All the potato cultivars were harvested on the same day (6 September 2011 or 21 August 2012).

From BBCH 39 phase (crop cover complete), potatoes were treated three times, at 10- to 14-day intervals, with biostimulators in doses recommended by the manufacturers:

– 0.1% solution of Asahi SL (contains phenols naturally occurring in plants: sodium ortho-nitrophenol, sodium para-nitrophenol, sodium 5-nitroguaiacol);

– 1.0% solution of Bio-Algeen S90 (extract from marine algae, contains amino acids, vitamins, alginic acid as well as macro- (N – 0.2, $P_2O_5$ – 0.06, $K_2O$ – 0.96, CaO – 3.1 and MgO – 2.1 $g \cdot kg^{-1}$) and micronutrients;

– 0.2% solution of Kelpak SL (extract from the brown seaweed *Ecklonia maxima* (11 mg $dm^{-3}$ and auxins and 0.031 mg $dm^{-3}$cytokinins; the auxin to cytokinin ratio is 350:1).

The control treatment consisted of potatoes not treated with any biostimulators.

After harvest, the potato yield was determined and samples were collected for chemical analyses. The remaining tubers were stored for 5 months at the temperature of 4°C. Afterwards, they were submitted to chemical analyses.

The dried and milled plant material was digested in concentrated sulphuric (VI) acid with hydrogen dioxide as an oxidant. The following determinations were performed on the prepared plant material: the content of phosphorus by spectrophotometry with the vanadium-molybdenum method; the concentrations of potassium, calcium and sodium by emission, and the magnesium content by atomic absorption spectrophotometry.

The analytical results underwent statistical processing by analysis of variance (STATISTICA 10 software) and the significance of differences was verified with the Tukey’s test at the level of significance p=0.05.

## RESULTS AND DISCUSSION

During the growth of the plant, both the average air temperature and total precipitations were higher than the multi-year average (Table 1).

Temperatures higher than multi-year average ones were observed in nearly every month of the growing season. Much higher rainfall was noted in 2011. After a dry spring (April - May), there was a surplus of rain in summer, especially in July (269% of the multi-year average) and August (120%). In 2012, too, the sum of precipitations during the potato’s growing season exceeded the long-term means. After a wet April, the total rainfall in May was close to the multi-annual average for that month. However, June and

July were again extremely wet (130% and 160% of the multi-year average amounts for 1961-2010, respectively). The deficit of rain re-appeared in the late plant growing season.

*Table 1*. Weather conditions

| Month | Temperature (°C) | | | Rainfall (mm) | | |
|---|---|---|---|---|---|---|
| | 2011 | 2012 | On average for years 1961-2010 | 2011 | 2012 | Sum for years 1961-2010 |
| April | 9.1 | 7.8 | 7.0 | 22.5 | 73.1 | 34.2 |
| May | 13.1 | 13.4 | 12.7 | 51.1 | 51.7 | 54.6 |
| June | 17.1 | 15.0 | 15.9 | 81.7 | 103.2 | 79.0 |
| July | 17.9 | 19.0 | 18.0 | 202.8 | 121.0 | 75.4 |
| August | 17.6 | 17.7 | 17.3 | 82.1 | 45.1 | 68.7 |
| Average/ sum | 15.0 | 14.6 | 14.2 | 440.2 | 394.1 | 311.9 |

In the first year of the field experiment, potato tubers contained on average 12.9% more phosphorus than in the second year (Table 2). The cultivar Sylvana contained significantly more P (3.75 g $kg^{-1}$ d.m.), while cv. Satina had significantly the lowest content of this element (3.33 g $kg^{-1}$ d.m.). The levels of phosphorus in tubers of the cultivars Irga and Volumina were similar (3.60 and 3.53 g $kg^{-1}$d.m.). The highest content of phosphorus was found in tubers of potatoes treated with Asahi SL (3.64g $kg^{-1}$ d.m.), while the plants sprayed with Bio-Algeen S90 had the smallest concentration of this element (3.48 g $kg^{-1}$ d.m.). Finally, the concentrations of phosphorus in tubers of control and Kelpak SL treated potatoes were similar (3.54 and 3.57 g $kg^{-1}$ d.m.).

*Table 2*. Content of minerals in potato tubers after harvest

| Specification | | P | K | Na | Ca | Mg |
|---|---|---|---|---|---|---|
| | | g·$kg^{-1}$ d.m. | | | | |
| Year | 2011 | 3.77±0.10 | 36.85±1.19 | 0.058±0.003 | 4.02±0.20 | 1.38±0.08 |
| | 2012 | 3.34±0.08 | 45.27±2.05 | 0.058±0.004 | 3.91±0.08 | 1.30±0.04 |
| Bioregulator | Control | 3.54±0.19 | 42.73±2.94 | 0.066±0.005 | 4.08±0.22 | 1.34±0.11 |
| | Asahi SL | 3.64±0.19 | 44.40±1.18 | 0.058±0.010 | 4.40±0.20 | 1.47±0.13 |
| | Bio-Algeen S90 | 3.48±0.13 | 39.39±1.81 | 0.057±0.008 | 3.65±0.20 | 1.25±0.06 |
| | Kelpak SL | 3.57±0.20 | 40.74±1.82 | 0.052±0.003 | 3.73±0.19 | 1.31±0.05 |
| Cultivar | Volumia | 3.60±0.08 | 42.06±1.72 | 0.054±0.006 | 4.12±0.23 | 1.39±0.08 |
| | Irga | 3.53±0.19 | 40.71±1.73 | 0.056±0.003 | 3.25±0.18 | 1.29±0.11 |
| | Satina | 3.33±0.16 | 40.74±1.29 | 0.061±0.004 | 3.86±0.15 | 1.27±0.11 |
| | Sylvana | 3.75±0.13 | 43.74±2.44 | 0.061±0.007 | 4.02±0.21 | 1.42±0.05 |
| F-distribution | Year | 341.89 | 314.07 | 0.01 | 2.20 | 6.83 |
| | Bioregulator | 7.12 | 31.68 | 1.59 | 19.17 | 8.74 |
| | Cultivar | 55.65 | 13.40 | 0.53 | 2.99 | 5.70 |
| p-value | Year | 0.00 | 0.00 | 0.916 | 0.148 | 0.014 |
| | Bioregulator | 0.00 | 0.00 | 0.211 | 0.000 | 0.000 |
| | Cultivar | 0.00 | 0.00 | 0.665 | 0.046 | 0.003 |
| HSD $p \leq 0.05$ | Year | 0.05 | 0.80 | n.s. | n.s. | 0.06 |
| | Bioregulator | 0.08 | 1.36 | n.s. | 0.27 | 0.11 |
| | Cultivar | 0.08 | 1.36 | n.s. | 0.27 | 0.11 |

In the second year of the study, potato tubers were richer in potassium by 22.8% compared to the first year. Analogously to the content of phosphorus, the highest concentration of potassium was determined in tubers of the cultivar Sylvana, which was 4% higher than in control tubers and 7.4% higher than in tubers of the cultivars Irga and Satina. Sprays with Kelpak Sl or BioAlgeen S90 resulted in a significant decrease in the content of K in tubers versus the control (by 4.6% and 7.8%, respectively). In turn, the effect of Asahi SL was the content of potassium in tubers higher by 3.9% than in the control.

The experimental factors did not affect the content of sodium in potato tubers, while the content of Ca depended on both cultivar-specific traits and the applied biostimulators. Similarly to P and K, the highest amount of Ca was found in tubers of potato plants treated with Asahi SL (7.9% more than in the control treatment). The use of Bio-Algeen S90 and Kelpak SL, however, resulted in a lower content of this element than in the control (by 13.1 and 8.6%, respectively). The cultivars Irga and Satina contained significantly less Ca than Volumia and Sylvana.

The significantly highest content of magnesium was determined in potato tubers treated with Asahi SL (1.47 g $kg^{-1}$ d.m.). In contrast, tubers of potato plants sprayed with Bio-Algeen S90 or Kelpak SL contained similar levels of Mg as the control tubers. The content of Mg in tubers of the cultivars Irga and Satina was significantly lower than in tubers of Volumia and Sylvana.

The content of mineral components in potato tubers, such as potassium, phosphorus and magnesium, depends on a genotype of plants but it is also shaped by the weather conditions and applied crop management treatments (mainly fertilisation) and soil properties (Dresow et al., 2013; Galdón et. al., 2012; Whittaker et al., 2010; Wichrowska et al., 2009). Lombardo et al. (2014) claimed that a cultivation system can also affect ‘the mineral profile’ of potato tubers. Early potato cultivars from organic farming contained more phosphorus while their content of magnesium and copper was comparable to that found in tubers from conventional potato farms. On the other hand, the highest concentrations of potassium, calcium, iron, sodium and magnesium were accumulated in tubers of potato grown in the conventional system. American studies, however, have demonstrated that potatoes from organic farms had more magnesium and copper but less iron and sodium, with similar levels of calcium, potassium and zinc as in potato tubers from conventional farms (Griffiths et al., 2012). Ciećko et al. (2012) reported that the content of macronutrients in tubers tended to decline in response to increasing doses of foliar nitrogen fertilisers, where the Ca : P and Ca : Mg ratios were narrowed while the K:(Ca + Mg) and K:Ca rations widened. According to Zarzecka and Gugała (2010), there was more phosphorus in potato tubers from a reduced cultivation system, but more calcium accumulated in tubers from the conventional system. Herbicides applied to potato caused a decrease in the P content and an increase in Ca compared to tubers from the control plot. In the study by Wichrowska et al. (2009), tubers harvested from herbicide-treated plots had more protein (by 3.7%), phosphorus (by 8.1%) and potassium (by 3.5%) than tubers of potato plants weeded only mechanically. In turn, Horvat et al. (2014) showed that the biostimulator Drin increased neither the content of chlorophyll and carotenoids in potato leaves nor the dry matter yield of tubers versus the control. Różyło and Pałys (2009) demonstrated that the content of phosphorus, potassium and magnesium in potato tubers was negatively correlated with the yield of dry matter of weeds. According to Ciećko et al. (2004), NK and P fertilisation had only a slight effect on the content of crude ash and individual macroelements in potato tubers, and it was only the concentration of P in tubers that increased in response to growing doses of phosphorus fertilisers. On the other hand, the content of macroelements was significantly dependent on the atmospheric conditions, and especially on amounts of rainfall. Higher concentrations of phosphorus, calcium and magnesium were found in potato tubers grown in years with less atmospheric precipitation.

Subramanian et al. (2011) underlined that the spatial distribution of minerals in potato tubers is not uniform. Concentrations of most minerals were higher in the peel than inside a tuber. The potato peel contained about 17% of the total Zn amount, 34% of Ca and 55% of Fe. In the fresh matter of tubers, higher concentrations of these elements were found in the stolon region of a tuber while the highest K concentration occurred in the apex. Concentrations of P, Ca and Cu decreased from the edge towards the centre of a tuber. Šrek et al. (2012), too, showed that the content of many elements was higher in the peel than in peeled tubers, but the differences regarding trace elements were relatively small. According to Whittaker et al. (2010), the content of reducing sugars, which conditions the culinary value and processing suitability of tubers, is negatively correlated with the content of potassium and calcium in potato tubers.

In the study by Maciejewski et al. (2007), the biostimulators Asahi SL and Atonik SL did not affect the structure of tuber yields or their content of dry matter, while the influence of these substances on the tuber content of reducing sugars depended on a cultivar. Similarly, Asahi SL had a weak effect on the content of minerals in aubergine fruits (Majkowska-Gadomska and Wierzbicka, 2013).

The uptake of macronutrients by potato tuber yield (Wierzbowska et al., 2015) was mainly dependent on a cultivar, while the biostimulators did not have a significant effect on the removal of these elements with yield (Figure 1). The potato yield accumulated the highest amounts of potassium - 209-445 kg ha$^{-1}$. The amounts of P and Ca accumulated in tuber yields were approximately the same (18.3-37.5 and 19.0-42.0 kg ha$^{-1}$, respectively), while the accumulation of Mg reached 7.6-11.6 kg ha$^{-1}$. Most mineral components were absorbed by the highest yielding cultivar Satina, while cv. Sylvana, whose yield was over two-fold lower, took up the smallest quantities of mineral elements.

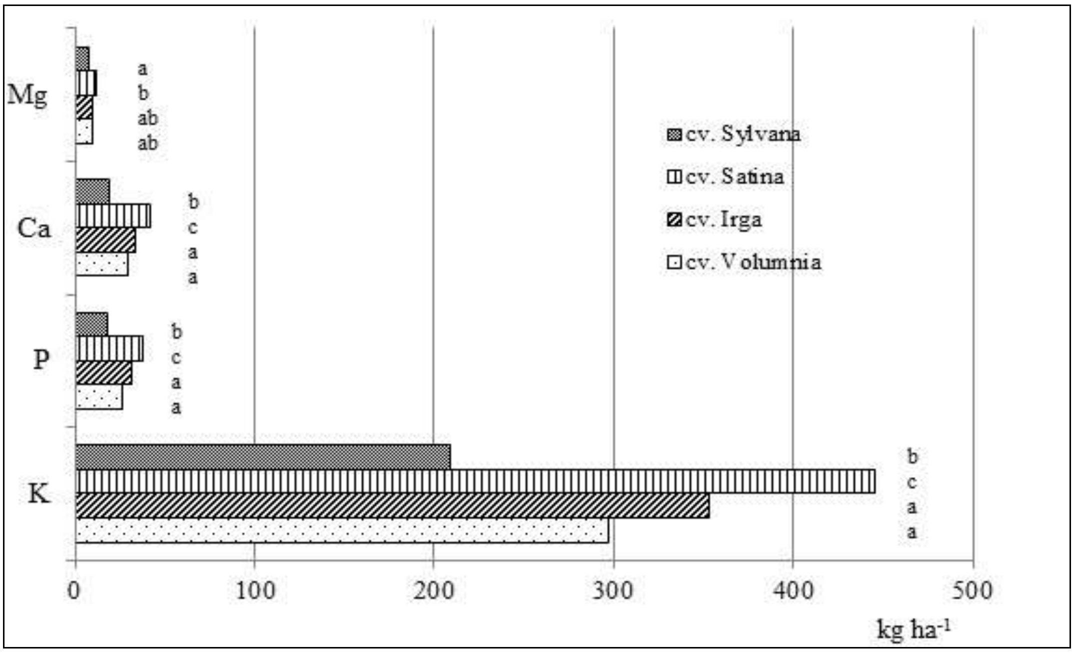


*Figure 1.* Uptake of nutrients by potato tuber yield (data regarding individual elements and assigned the same letter do not differ significantly at p≤0.05)

Zarzecka and Gugała (2010) showed that the uptake of phosphorus and calcium by potato tuber yield was significantly higher in treatments with the traditional cultivation system than from the plots with reduced cultivation, and from the plots weeded chemically than from the ones where weeds were removed only mechanically. Tein et al. (2014) claim that all quality parameters of potato tubers are to some extent correlated and a deficiency or excess of some elements may affect others. Potato cultivation involves an uptake of considerable amounts of nutrients from the soil store, which in extreme cases may lead to the impoverishment of soil.

*Table 3*. Changes in the content of minerals in potato tubers after storage

| Specification | | P | K | Na | Ca | Mg |
|---|---|---|---|---|---|---|
| | | % | | | | |
| Year | 2011 | 6.81 | 5.60 | 37.12 | 18.02 | 20.53 |
| | 2012 | 4.46 | 5.99 | 57.03 | 27.23 | 25.55 |
| Bioregulator | Control | 5.87 | 5.03 | 43.89 | 24.96 | 26.00 |
| | Asahi SL | 5.17 | 7.48 | 52.15 | 20.02 | 24.79 |
| | Bio-Algeen S90 | 5.50 | 3.44 | 45.58 | 30.95 | 20.07 |
| | Kelpak SL | 5.99 | 7.24 | 46.68 | 14.56 | 21.30 |
| Cultivar | Volumia | 4.77 | 5.48 | 52.33 | 22.40 | 19.55 |
| | Irga | 6.83 | 5.59 | 44.29 | 24.13 | 25.13 |
| | Satina | 5.59 | 6.76 | 45.89 | 21.07 | 25.66 |
| | Sylvana | 5.35 | 5.37 | 45.79 | 22.89 | 21.84 |
| F-distribution | Year | 19.93 | 0.33 | 16.55 | 14.57 | 3.78 |
| | Bioregulator | 0.51 | 8.00 | 0.53 | 8.40 | 1.18 |
| | Cultivar | 2.73 | 0.92 | 0.53 | 0.28 | 1.24 |
| p-value | Year | 0.000 | 0.570 | 0.000 | 0.001 | 0.061 |
| | Bioregulator | 0.679 | 0.000 | 0.662 | 0.000 | 0.331 |
| | Cultivar | 0.060 | 0.443 | 0.662 | 0.842 | 0.310 |
| HSD p≤0.05 | Year | 1.07 | n.s. | 10.00 | 4.93 | n.s. |
| | Bioregulator | n.s. | 2.36 | n.s. | 8.42 | n.s. |
| | Cultivar | n.s. | n.s. | n.s. | n.s. | ns. |

In the consequence of transformations occurring during the storage of potato tubers, their content of mineral components increased (Table 3). The concentration of phosphorus increased to the highest degree in the first year of the experiment, while that of sodium and calcium rose the most in the second year. It was only in the case of potassium and calcium that a significant, residual effect of the growth stimulators was detected. The content of K increased the most (by 7.48%) in potato tubers treated with Asahi SL, and the least (by 3.44%) after the application of Bio-Algeen SL90. The content of Ca in tubers increased by 14.56% under the residual effect of Kelpak SL, and by over 30% when Bio-Algeen SL90 had been applied. According to Mărghitaş et al. (2011), balanced organic and mineral fertilisation, which takes into account the nutritional demands of this crop, allows for reduction of total tuber storage losses. Higher losses during storage were observed in years with high atmospheric precipitations (Ciećko et al., 2001). Wichrowska et al. (2009) reported that the content of phosphorus and potassium did not change significantly in potato tubers stored at the temperature of 4°C, whereas at 8°C those changes tended to be significant.

## CONCLUSIONS

The weather conditions during the growing season of the potato crop can largely affect the content of some macronutrients (phosphorus, potassium, magnesium) in tubers.

Spraying potato plants with the preparation Asahi SL increased the content of minerals in tubers, conversely to the application of Bio-Algeen S90 or Kelpak SL, which resulted in their lower content.

A higher concentration of macroelements in the dry matter of tubers was characteristic for the cultivars Volumia and Saylvana.

In the consequence of the transformations occurring in potato tubers during their storage, their content of mineral components increased.

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