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ORIGINAL PAPER

CONTENT OF MACROELEMENTS IN TUBERS OF SEVERAL POTATO VARIETIES DEPENDING ON THE FOLIAR FERTILIZATION APPLIED*

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Abstract

The aim of the study was to determine the effect of foliar fertilizers containing macro- and microelements, and used in the form of chelates, on the content of macroelements in tubers of several potato varieties. The study was based on a 3-year (2013-2015) field experiment conducted in Haczow (49°39′40″N, 21°53′49″E), on brown, slightly acidic soil. The experiment was established using the method of random subblocks, where the first order factors were foliar fertilization treatments with the following fertilizers: Fortis Duotop Zn Mn + Fortis Aminotop (A), Fortis B Mo + Ferti Agro (B), Fortis Zn Mn + Fortis B Mo (C) and the control object, without foliar fertilization. The second order factors were 4 potato varieties belonging to different classes of earliness (Agnes, Jelly, Viviana, Vineta). Foliar application of all fertilizer combinations contributed to an increase in the magnesium content, while the application of Fortis B Mo + Ferti Agro fertilizers increased the nitrogen and potassium content. Genetic traits differentiated the content of macroelements. Tubers of the cultivar Jelly were characterized by the largest accumulation of phosphorus, potassium, magnesium and calcium, while the Viviana cultivar had the smallest amounts of phosphorus, potassium, calcium. The meteorological conditions in the years of the experiment modified the content of macroelements. Under the dry summer conditions but very wet September in 2013, the tubers accumulated most magnesium and calcium, but contained the least nitrogen, phosphorus and potassium. With excess precipitation in 2014, the tubers were found to contain the most phosphorus, potassium and calcium, while in the dry 2015 year, with a significant shortage of precipitation during the potato growing season and air temperature higher than the long-term average, the tubers accumulated the highest nitrogen but the lowest calcium amounts.

Keywords: potato, foliar fertilization, macroelement.

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INTRODUCTION

Modern technologies in potato production involve appropriate nutrient management. Rational supply of plants with nutrients allows us to limit any unfavorable impact of growth and development conditions and to achieve an appropriate quality of tubers (TRAWCZYŃSKI 2019, KOCH et al. 2020). An alternative way of supplying the plant with the missing nutrients is foliar fertilization. It allows farmers to provide plants with microelements and trace elements quickly and effectively, by sprinkling the leaves with an aqueous solution of mineral salts or chelates (QUADRI et al. 2015, JASIM, MERHIJ 2018). According to NOAEMA (2018), foliar fertilization allows one to improve otherwise poor plant nutrition or supplement deficiencies of some bioelements. It also let us provide nutrients during periods of drought, intensive growth and development of plants and in situations where agrotechnical errors have been made. Particularly intensive intake of nutrients is possible through the leaves of young plants, whereas older leaves, after maturity, are not able to provide nutrients (KOCH et al. 2020).

The potato's nutritional value is influenced by vitamins, proteins, carbohydrates and minerals. These compounds constitute building material for bones, teeth, skin and hair, and they are of fundamental importance for metabolic processes, as they regulate water-electrolyte balance and maintain acid-base balance in the body, as well as having various other regulating effects (WOJTASIK et al. 2012). Potatoes are an important component of the human diet in many countries around the world. They provide macro- and microelements necessary for the proper functioning of the body.

Therefore, the aim of the study was to determine the effect of foliar fertilizers with the content of macro- and microelements used in the form of chelates on the content of macroelements in tubers of the tested potato varieties. The study verified the research hypothesis that foliar fertilization has a beneficial effect by increasing the macroelement content, compared to the zero hypothesis suggesting that there are no differences between the objects in which foliar fertilization is applied.

MATERIALS AND METHODS

The research was based on a 3-year field experiment carried out in Haczow (49°39′40″N, 21°53′49″E), on brown, slightly acidic soil. The experiment was established using the method of randomly selected subblocks, in a split-plot arrangement, where foliar fertilizers were first order factors: Fortis Zn Mn + + Fortis Aminotop (A), Fortis B Mo + Ferti Agro (B), Fortis Zn Mn + Fortis B Mo (C) and standard object, without foliar fertilization (D). The second order factors were edible potato varieties from different groups of earliness

(Viviana – very early, Vineta – early, Agnes – medium early and Jelly – medium late). Foliar fertilizers used in the experiment were characterized by the following chemical composition:

– Ferti Agro is a fertilizer containing the following amounts of components: nitrogen – 10%, phosphorus – 45%, potassium – 5%, boron – 0.05%, copper – 0.1%, iron – 0.05%, manganese – 0.1%, zinc – 0.4%, magnesium – 2%, sulphur – 8%, molybdenum – 0.01%, and also amino acids and vitamins.
– Fortis Aminotop is a fertilizer containing 9% organic nitrogen, soluble amino acids, aspartic acid – 0.46%, glutamic acid – 3.50%, serine – 0.21%, histidine – 0.04%, glycine – 4.16%, treonine – 0.04%, allanine 1.71%, arginine 0.11%, tyrosine 0.47%, valine 0.09%, methionine 0.06%, phenylalanine 0.24%, isoleucine 0.28%, leucine 0.29%, lysine 0.23%, hydroxypoline 0.77%, proline 1.36%.
– Fortis B Mo is a fertilizer containing boron 11% and molybdenum 0.37%.
– Fortis Duotop Zn Mn contains zinc – 7.1%, manganese – 5.1%, copper – 0.033%, boron – 0.024%, molybdenum – 0.003% and magnesium – 0,2%.

In the experiment, the fertilizers were used in the following combinations: A – Fortis Duotop Zn Mn + Fortis Aminotop, B – Fortis B Mo + Ferti Agro, C – Fortis Duotop Zn Mn + Fortis B Mo.

In autumn, manure fertilization at a dose of 25 t ha^{-1} and phosphorus-potassium fertilization in the amounts: 44 kg P and 124 kg K ha^{-1} were applied. In spring, nitrogen fertilization was applied in a single dose, as urea in the amount of 80 kg N ha^{-1}. Seedstock in D/A degree was planted in the last ten days of April, spaced at 70 x 38 cm. The preceding crop for potato was winter barley.

Foliar fertilizers were applied according to the producers' recommendations from the last ten days of May (BBCH phase 29) until the beginning of fruit formation (BBCH phase 71) – Bleiholder et al. (2005). Depending on the combination of fertilizers used, they were applied in the first and the last ten days of June and in the first, second and third ten-day periods of July. Fert Agro fertilizer was applied at a dose of 3 kg ha^{-1}, four times every 7 days, starting from the stage of lateral shoot development, Fortis Aminotop at a dose of 2-3 dm^3 ha^{-1}, four times, starting from the moment the plant reached the height of 15-20 cm, every 10-15 days, Fortis B Mo at a dose of 1-1,5 dm^3 ha^{-1}, twice: the first dose in the period from the formation of shoots to the shortening of rows, the second dose - in the period from the formation of tubers and inflorescences, while Fortis Duotop Zn Mn was applied twice, when the plants were 10-15 cm and 15 days later, at a dose of 2-3 dm^3 ha^{-1}. After planting the tubers, mechanical and chemical treatments were applied, which included ridging. Afterwards, Plateen 41.5 WG was applied at a dose of 2 kg ha^{-1}. During the plant growing period, protection against potato diseases and beetle infestation was carried out in accordance with the recommendations of the Institute of Plant Protection-PIB.

The tubers were harvested in the period of technical maturity, in the last ten days of August (very early and early varieties) and in the second ten-day period of September (medium early and medium late varieties).

Soil conditions

Soil samples were taken in the autumn, after harvesting the preceding crop, with a soil stick, from the top soil layer, from a depth of up to 20 cm. A total sample weighed 300-500 g and was a mixture of about 20 primary samples. The experiment was carried out on brown soil, formed from silt deposits, with the mechanical composition of clay dust (PTG 2019) – Table 1.

Table 1

Granulometric composition of soil (%)

Years	Percentage of the fraction with diameter (mm)						Mechanical composition
	2.0-1.0	1.0-0.5	0.5-0.05	0.05-0.005	0.005-0.002	<0.002	
2013	0.00	2.86	34.32	48.03	8.67	6.12	clayey dust
2014	0.00	2.84	34.40	48.00	8.67	6.15	clayey dust
2015	0.00	2.86	34.35	48.10	8.70	6.12	clayey dust
Mean	0.00	2.85	34.36	48.04	8.68	6.13	

Source: own study based on the results of the Chemical-Agricultural Station in Rzeszów

This soil was characterized by slightly acidic reaction (5.69 pH in 1n KCl). The soil had a medium level of assimilable phosphorus and potassium, a very high level of magnesium and a medium level of copper, manganese, iron and zinc. The humus content in the arable layer was high, 2.66% on average (Table 2). The above data allowed us to classify the soil under study to the soil valuation class IVb, good rye complex.

Table 2

Physical and chemical properties of soil (2013-2015)

Years	Content of assimilable macronutrients (mg kg^{-1} of soil)			$CaCO_3$ (%)	Humus (g kg^{-1})	pH (KCl)	Micronutrient content (mg kg^{-1} of soil)			
	P	K	Mg				Cu	Mn	Zn	Fe
2013	54.9	166.0	197.0	0.02	2.71	5.66	5.6	175	14.3	1591.0
2014	52.3	166.0	195.0	0.02	2.55	5.70	5.9	174	14.5	1575.0
2015	54.5	168.0	199.0	0.01	2.72	5.70	5.3	175	14.4	1589.0
Mean	53.9	167.0	197.0	0.02	2.66	5.69	5.6	174.8	14.4	1585.0

Source: Chemical-Agricultural Station in Rzeszów

Sampling for chemical analysis

Tubers for testing were taken during the harvest. From each variant, about 60 medium size (50-60 mm) tubers, characteristic for the variety, were collected from to make a composite sample for laboratory tests. The evaluation of the tubers was carried out in autumn, directly after harvesting.

In dry matter of potato tubers determined by the weight-drying method the content of phosphorus was determined by vanadium-molybdenum method, the content of potassium by flame photometry according to Johnson (Krełowska-Kułas 1993), while the content of magnesium and calcium was determined by atomic absorption spectrometry ASA (AOAC 2006). All chemical analyses were performed in 3 repetitions for each field experiment combination.

Meteorological conditions

The meteorological conditions during the years of the study were diverse. The year 2013 was characterized by very dry July and August, during the period of maximum tuber yield accumulation, while June and September were characterized by excessive rainfall (Table 3). During the whole vegeta-

Table 3

Qualification of potato growing period according to the Selyaninov hydrothermal coefficient

Year	Month	Total precipitation (mm)	Average temperature (°C)	Selyaninov hydrothermal coefficient	
2013	April	30.6	9.5	1.1	fairly dry
	May	80.5	14.5	1.8	fairly moist
	June	126.5	17.6	2.4	moist
	July	30.2	18.7	0.5	very dry
	August	30.7	18.6	0.5	very dry
	September	92.5	11.6	2.7	very moist
Mean				1.5	optimal
2014	April	63.7	10.0	2.1	moist
	May	119.0	13.4	2.9	very moist
	June	52.9	16.0	1.1	fairly dry
	July	164.2	19.6	2.7	very moist
	August	67.9	17.4	1.3	fairly dry
	September	31.3	14.9	0.7	very dry
Mean				1.8	fairly moist
2015	April	28.2	8.3	1.1	fairly dry
	May	98.2	12.1	2.6	very moist
	June	26.2	15.7	0.6	very dry
	July	63.1	20.1	1.0	dry
	August	10.6	20.5	0.2	extremely dry
	September	108.0	15.3	2.4	Most
Mean				1.3	fairly dry

Source: own study according to IMGW-PIB, Hydrological-Meteorological Station in Krosno tion period the sum of precipitation was 90,3% of the sum of long-term precipitation, the lowest level of precipitation, compared to the long-term norm, was observed in July. The average temperature in the third decade of April, when the potatoes were planted, was high and was 15°C. Relatively high temperatures in the last decade of April and May were conducive to fast potato growth. In the same year the average temperature was 0,9°C lower than the long-term average.

In 2014, the months of April and May were cold and wet, June and July were quite warm, and July was characterized by excess rainfall, compared to the long-term norm. The year 2014 was characterized by excess rainfall, compared to the water requirements of a potato. The total precipitation, compared to the long-term average, was the highest in comparison with the remaining years of the study. The temperature distribution in the vegetation period favored potato development. The average temp. showed a slight deviation from the perennial average, while the average temperature was 1.2°C higher than the perennial average.

The year 2015 was characterized by the lowest amount of precipitation during the study period. The total precipitation was 70.2% of the long-term average. The rainfall in the second vegetation period did not provide even 50% of the water demand of potato plants. Months of June and July were dry months, and August was extremely dry. May, on the other hand, was a very humid month, and in September the rainfall exceeded the long-term norm. In August, the average air temp. was 2.2°C higher than the long-term average.

Statistical calculations

Statistical analysis of the test results was based on the model of a three-factorial analysis of variance and multiple *t*-Tukey tests. The results were subjected to the analysis of variance (ANOVA) and repeated *t*-Tukey tests, at the significance level of *p* 0.05. Moreover, the coefficients of variation were calculated for the whole experiment. They are measures of random variability in the experiment. All analyses were performed using the GenStat 18 statistical software package.

RESULTS

The average nitrogen content in dry matter of potato tubers was 13.26 g kg^{-1} (Table 4). Foliar fertilization had a significant effect on the content of this component in tuber dry matter. The highest content of this macroelement was recorded after the application of Fortis B Mo + Ferti Agro fertilizers, while the lowest one was recorded in response to Fortis Duotop Zn Mn + + Fortis B Mo. The remaining objects proved to be homogeneous in terms

Table 4

Influence of cultivars, fertilization and years of cultivation on macroelement content in dry matter of potato tubers (g kg^{-1})

Experimentation factors		N	P	K	Mg	Ca
Fertilization*	0	13.24*b*	2.09*a,b*	22.67*a*	1.04*b*	2.53*a*
	A	13.35*b*	2.02*b*	22.26*b*	1.16*a*	2.53*a*
	B	13.63*a*	2.12*a,b*	22.62*a*	1.14*a*	2.58*a,b*
	C	12.88*c*	2.08*a,b*	22.52*a*	1.15*a*	2.59*a,b*
	$HSD_{0,05}$	0.66	0.09	0.40	0.06	0.05
Cultivars	Agnes	12.58*c*	2.16*b*	22.36*c*	1.07*b*	2.60*b*
	Jelly	13.16*b*	2.27*a*	24.11*a*	1.14*a*	2.67*a*
	Viviana	13.35*b*	1.98*c*	20.84*d*	1.13*a*	2.44*d*
	Vineta	14.01*a*	1.90*c*	22.76*b*	1.15*a*	2.52*c*
	$HSD_{0,05}$	0.66	0.09	0.40	0.06	0.05
Years	2013	11.63*c*	1.81*c*	21.24*c*	1.15*a*	2.61*a*
	2014	12.77*b*	2.28*a*	23.55*a*	1.10*b*	2.62*a*
	2015	15.43*a*	2.14*b*	22.76*b*	1.12*b*	2.44*b*
	$HSD_{0,05}$	0.50	0.07	0.30	0.04	0.04
Mean		13.26	2.08	22.52	1.11	2.56
RSD (%)		2.64	6.23	1.38	6.97	4.19

* 0 – control object without foliar fertilization, A – Fortis Duotop Zn Mn + Fortis Aminotop, B – Fortis B Mo + Ferti Agro, C – Fortis Duotop Zn Mn + Fortis B Mo

of this feature. Among the tested varieties, Vineta was characterized by the highest nitrogen content. Significantly lower content of this macroelement was recorded in the Jelly and Viviana varieties. These cultivars were homogeneous with respect to the analyzed trait. The lowest nitrogen content was in the Agnes variety tubers. Atmospheric conditions in the consecutive years significantly determined the nitrogen content in the dry matter of tubers. The highest value of this trait was recorded in the very dry year 2015. Significantly lower nitrogen content was found in warm and moist 2014, while the lowest one was in 2013, with dry July and August, but very wet September.

The content of phosphorus, which is an element necessary for the proper functioning of each cell and many compounds that are the primary source of energy of all biochemical reactions taking place in living organisms (Bezak-Mazur, Stoińska 2013), was 2.08 g kg^{-1} of tuber dry matter on average (Table 4). The application of Fortis B Mo + Ferti Agro fertilizers resulted in a significant increase in the phosphorus content only in relation to the object with the application of Fortis Duotop Zn Mn + Fortis Aminotop. The fertilizers Fortis Duotop Zn Mn + Fortis B Mo, Fortis B Mo + Ferti Agro and the control proved to be homogeneous in terms of the value of this feature. Varietal properties significantly shaped the content of this element in tubers. The most phosphorus was accumulated by the Jelly tubers (medium--late variety) and the least - by Vineta (early variety). Viviana and Vineta turned out to be homogeneous in terms of this feature. The Agnes variety contained significantly less of this element in the tubers than Jelly, but significantly more than Viviana and Vineta. Meteorological conditions in the years of the study significantly shaped the phosphorus content in the dry matter of tubers. The greatest amount of this element was accumulated by tubers in warm and moist year 2014, and the least – in meteorologically average year 2013.

The content of potassium, an element participating in protein synthesis and in carbohydrate metabolism as well as increasing the intensity of photosynthesis and the rate of assimilate transfer from leaves to other plant organs (Burrowes, Ramer 2008, Abd El-Latif et al. 2011, Njira, Nabwami 2015), was 22.52 g kg^{-1} of tuber dry matter (Table 4). Foliar application of Fortis Duotop Zn Mn + Fortis Aminotop fertilizers resulted in a decrease in the content of this element in potato tubers, compared to the control object. The potassium content in the remaining combinations with foliar fertilization and in the control object turned out to be homogeneous in terms of the values of this characteristic. The potassium content in the dry matter of tubers was significantly influenced by varietal characteristics. The variety Jelly was the most abundant in this element, while Viviana was the least abundant one. The Vineta variety was the second and Agnes the third in terms of the abundance of this important element in human nutrition. Meteorological conditions significantly differentiated the potassium content in the dry matter of tubers. Most of this macroelement was accumulated by the tubers in warm and humid 2014, and the least was accumulated in 2013, when July and August were very dry while June and September were rainy.

The average content of magnesium, an element included in chlorophyll, very important for maintaining the proper ribosome structure, taking part in the synthesis of nucleic acids and proteins, and transmitting signals in the nervous system (Njira, Nabwami 2015), was 1.11 g kg^{-1} of tuber dry matter (Table 4). All fertilizer combinations contributed to an increase in the magnesium content, with the tubers from the plots to which the fertilizers were applied being homogeneous in terms of characteristics. The cultivars studied differed significantly in the abundance in this element. The tubers of the Vineta variety were most abundant in magnesium and those of the Agnes variety were the least abundant in this element. The cultivars Jelly, Viviana and Vineta were homogeneous in values of this trait. The biggest amount of magnesium was accumulated by the tubers in 2013, when there was excessive rainfall in June and September, while July and August were very dry. In the remaining years of the study, the tubers of the examined cultivars accumulated significantly less of this element; it should be added that the magnesium content of tubers in the years 2014 and 2015 was homogeneous with respect to the values of this trait.

The content of calcium, an element which acts as a structural and information transmitter in human and animal organisms (Wińska-Krysiak 2006), was 2.56 g kg^{-1} of tuber dry matter on average (Table 4). Foliar application of fertilizers: Fortis B Mo + Ferti Agro as well as Fortis Duotop Zn Mn + + Fortis B Mo significantly increased the calcium content of potato tubers compared to the control object; the amount of this element in both combinations proved to be homogeneous. The foliar application of fertilizers Fortis Duotop Zn Mn + Fortis Aminotop did not have a significant effect on the accumulation of calcium in potato tubers. Among the tested cultivars, Jelly accumulated significantly most calcium in the tubers, while the Viviana tubers had the lowest content of this element. The Agnes variety was the second and Vineta was the third in terms of the calcium content in tubers. Most calcium was accumulated by the tubers of the analyzed varieties in 2014, while the lowest accumulation of calcium took place in 2015. However, it should be added that the content of this element in the tubers in 2013 and 2014 was homogeneous with respect to the values of this trait (Table 4). No interaction between the experimental factors has been shown in the experiment.

Coefficients of variation (RSDs) for the content of the macroelements studied were low, which proves high stability of these features (Table 4).

DISCUSSION

Potato tubers are a valuable source of minerals, such as potassium, phosphorus, magnesium and calcium (Leszczyński 2012, Żołnowski 2013, Zarzecka et al. 2015, Sawicka et al. 2016). Potassium influences ionic and water metabolism (Leszczyński 2012, Żołnowski 2013). Zarzecka et al. (2015), Kozera et al. (2006), and Wierzbicka (2012) obtained the potato tuber potassium content in the range from 13.1 to 25.9 g kg^{-1} d.m. According to USDA (2018) data, its amount in raw tubers is about 41.7 g kg^{-1} and changes during culinary processing. In our study, the average potassium content of 22.52 g kg^{-1} d.m. was obtained. The foliar fertilization used in the experiment decreased the content of this macroelement in the tubers of the cultivars.

Nitrogen is an important component of ash. It is an essential element for building proteins, as well as a component of many vitamins, alkaloids, nucleic acids and chlorophyll. It is therefore very important for the growth and development of plants (White et al. 2007, Njira, Nabwami 2015). The content of this element ranges from 18.21 to 22.53 g kg^{-1} d.m. (Zarzecka et al. 2015). In this experiment. the average content of 13.26 g kg^{-1} d.m. was obtained. Nitrogen is a component the amount of which largely depends on the applied organic and mineral fertilization (Wierzbicka 2012). This element is a component of proteins as well as harmful nitrates and nitrites. The fertilization applied in the experiment had a diverse effect on the nitrogen content in tubers of the tested varieties. The application of the combination of fertilizers Fortis B Mo + Ferti Agro contributed the most to the increase in the nitrogen content, while the lowest nitrogen content in potato tubers was recorded after the application of Fortis Duotop Zn Mn + Fortis B Mo.

Phosphorus is present in potato tubers in concentrations from 0.8 to 3.9 g kg^{-1} d.m., depending on a cultivation system, cultivar and year of research (Kozera et al. 2006, Wierzbicka 2012, Żołnowski 2013, Zarzecka et al. 2015). In this study, the determined levels of phosphorus were similar to the ones cited above, and the combined application of Fortis Duotop Zn Mn + Fortis Aminotop fertilizers caused a decrease in the phosphorus content.

In our research, the calcium concentration in the tubers of the tested cultivars was approximately 2.56 g kg^{-1} d.m. An increase in the content of this macroelement was induced by the combined application of the fertilizers Fortis B Mo + Ferti Agro and Fortis Duotop Zn Mn + Fortis B Mo. In this experiment, the magnesium content in the tubers was about of 1.11 g kg^{-1} d.m., and all the tested fertilizer treatments significantly increased the content of this macroelement.

Many authors (Kozera et al. 2006, Żołnowski 2013, Wierzbowska et al. 2015) have investigated the influence of fertilizers on the macroelement content in potato tubers. Rizk et al. (2013), testing foliar fertilization with 3% urea solution, found an increase in the nitrogen, phosphorus and potassium content. According to Żołnowski (2013), tubers fertilized intensively with foliar fertilizers contain increased amounts of nitrogen, phosphorus and magnesium. The number of tubers grown by potato plants which receive foliar fertilizers is also higher. Kozera et al. (2006) obtained a significant increase in the content of calcium, magnesium, phosphorus and sodium in tubers having applied foliar fertilizers with microelements, but simultaneously recorded a decrease in potassium. Mona et al. (2012) showed that foliar fertilizers contributed to an increase in the nitrogen, phosphorus and potassium content of potato tubers compared to objects where foliar fertilization was not applied, and the actual concentrations of these elements depended on the fertilizer used. Karlsson et al. (2006) noted an increase in the calcium content owing to the application of fertilizers which contained this element. El-Zohiri, Asfour (2009) also reported an increase in the calcium content under the influence of potassium sulphate and calcium nitrate, or potassium nitrate and calcium nitrate. Kozera and Barczak (2007), who tested the effect of the multicomponent fertilizer Mikrochelat Gama, containing copper, zinc and molybdenum, found an increase in the content of total nitrogen in potato tubers compared to the object without foliar fertilization. Quadri et. al. (2015), who applied increasing doses of phosphorus and nitrogen fertilization in the form of foliar application with urea, found a higher content of nitrogen, phosphorus and potassium in potato tubers, while Ciećko et al. (2012)

noted a decrease in the content of phosphorus, potassium, calcium and magnesium, with a simultaneous increase in sodium content in potato tubers under the influence of foliar application of urea, while the foliar application of magnesium did not significantly affect the content of these macroelements. Horvat et al. (2013) prove that foliar fertilization has no significant effect on the content of nitrogen, phosphorus and magnesium, but differently affects the content of potassium and calcium in tubers, depending on the applied foliar fertilizer. Mousavi et al. (2007), in an experiment with the foliar application of zinc and manganese, proved that these microelements did not affect the content of phosphorus and potassium in tubers, but caused an increase in the zinc and manganese content in tubers. Rasool et al. (2010), having applied potassium salt and macro- and microelements contained in foliar fertilizer, found an increase in the nitrogen, phosphorus and potassium content of tubers. Trawczyński and Korycki (2008) proved that the use of Campofort fertilizers did not affect the nitrogen and phosphorus content in dry matter, but simultaneously these fertilizers contributed to an increase in the tuber potassium content. Sparrow (2012), testing YaraVita Potato and Actisil fertilizers, did not show significant changes in the content of phosphorus, potassium and magnesium in tubers of the Jelly variety. In the current study, the tested foliar fertilizers had diverse effects on the content of macroelements in the tubers of the tested cultivars. The foliar fertilizers containing nitrogen, phosphorus, potassium and microelements significantly increased the content of nitrogen, potassium and magnesium. Fertilizers which – apart from microelements – provided the plants with amino acids and nitrogen contributed to the reduction in the phosphorus and potassium content. According to Quadri et al. (2015), a higher content of macroelements in tubers in response to the application of foliar fertilizers containing, nitrogen results from the fact that plants are better nourished, they carry out photosynthesis more intensively, and thus they can absorb nutrients from the soil more intensively. Ciećko et al. (2012) maintain that reduction in the ash content in tubers may be related to the dilution of minerals in the growing tuber mass (due to increasing nitrogen fertilization), which manifests itself as the reduction of dry matter and ash content.

The content of macroelements in potato tubers was significantly influenced by genetic traits of the varieties. This is confirmed by by Wierzbicka, Trawczyński (2011*a*,*b*), Wojdyła (2013), Żołnowski (2013), Wierzbowska et al. (2015). Wierzbicka and Trawczyński (2011*b*) proved that the varietal factor had a significant effect on the content of potassium, phosphorus, magnesium, copper, manganese and iron, but did not affect the nitrogen accumulation in tubers. The levels of phosphorus, potassium and magnesium in tubers of the examined cultivars were similar to the ones reported by Zarzecka et al. (2015). The phosphorus and magnesium content in tubers of the examined cultivars was similar to the one obtained by Wierzbicka et al. (2011*b*) and Żołnowski (2013).

The environmental conditions in the consecutive years of the experiment significantly differentiated the content of macroelements. Dry July and August and excess rainfall in June and September 2013 favoured the accumulation of magnesium, calcium and iron in tubers. In warm and humid year 2014, an increase in the content of phosphorus, potassium and calcium was recorded in the tubers, while in the driest of all the experimental years, such as 2015, nitrogen, zinc, manganese and copper accumulated more in potato tubers. The dependence of the content of macroelements on environmental factors is confirmed by Wierzbicka and Trawczyński (2011*b*) and Wierzbowska et al. (2015).

CONCLUSIONS

1. Foliar application of all fertilizer combinations contributed to an increase in magnesium content in tubers of the tested potato varieties. The application of Fortis Duotop Zn Mn + Fortis Aminotop fertilizers contributed to a decrease in potassium content and the application of Fortis Duotop Zn Mn + Fortis B Mo fertilizers contributed to a decrease in nitrogen content. The application of Fortis B Mo + Ferti Agro increased the nitrogen and potassium content.

2. Genetic traits differentiated the content of macroelements in the following way: cv. Agnes (medium-early) tubers contained the least amount of nitrogen and magnesium, tubers of cv. Viviana (very early variety) was characterized by the least phosphorus, potassium, calcium, and the Vineta (early) variety was characterized by the highest content of magnesium, nitrogen, but the lowest amount of phosphorus. The tubers of Jelly (medium late) cultivar were characterized by the highest accumulation of phosphorus, potassium, magnesium and calcium.

3. Meteorological conditions during the years of research modified the content of macroelements. Under dry summer conditions, but with very wet September in 2013 the tubers accumulated the most magnesium and calcium, but the least nitrogen, phosphorus and potassium. With excessive precipitation in 2014, the tubers were found to contain the most phosphorus, potassium and calcium, while in the dry year 2015, with a significant shortage of precipitation during the potato growing season and air temperatures higher than the long-term average, the potato tubers had the highest nitrogen content, but the lowest calcium.

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