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EFFECT OF BIODYNAMIC PREPARATIONS ON THE CONTENT OF SOME MINERAL ELEMENTS AND STARCH IN TUBERS OF THREE COLOURED POTATO CULTIVARS

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ABSTRACT

Biodynamic (BD) preparations 500 and 501 are plant strengthening agents of the biodynamic agriculture method, prepared from cow manure and powdered quartz. The resulting products are highly diluted and sprayed on soil and plants. The main purpose of these preparations is to promote the processes of energy and nutrient cycling as well as to improve plant and soil quality parameters. This study was carried out in 2013-2014, in order to evaluate the influence of biodynamic preparations 500 and 501 on the chemical composition of potato tubers: amounts of dry matter, starch and mineral elements (potassium, magnesium, phosphorus and nitrogen). The experiment included two factors: I – three coloured potato (*Solanum tuberosum* L) cultivars (Vitelotte, Blue Congo – purple flesh and Red Emmalie – red flesh), II – treatment with BD preparations as field sprays (four treatments: 1 – control sample (without BD preparations); 2 – BD preparation 500; 3 – BD preparation 501; 4 – a blend of two preparations (BD preparation 500 and BD preparation 501)). The research revealed that BD preparations 500 and 501 had no significant effect on the content of dry matter and mineral element in coloured potato tubers in any of the experimental variants. However, BP preparation 501, as well as a combination of both 500 and 501 BP preparations, increased the starch content in potato tubers significantly ($p < 0.05$). It was found that the quality indicators of potato tubers depended on the genetic characteristics of a cultivar. According to the two-year mean data, the significantly largest amounts of potassium (29.51 g kg⁻¹ d.m.) and magnesium (1.475 g kg⁻¹ d.m.) were accumulated in potato tubers of the cultivar Red Emmalie. Tubers of cv. Vitelotte accumulated the biggest amounts of dry matter (27.03%) and starch (18.17%).

Keywords: biodynamic preparations, coloured potato cultivars, starch, phosphorus, potassium, magnesium, nitrogen.

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INTRODUCTION

Owing to their higher nutritional value, appearance and flavour, potatoes with coloured flesh have attracted more attention among researchers and consumers in the past ten years. The tubers of these potatoes are an important source of biologically active substances (polyphenol, anthocyanins, carotenoids and ascorbic acid) for the human body (HAMOUZ et al. 2011, DANILCENKO et al. 2014). Also, they are rich in carbohydrates (starch), minerals, etc. (KING, SLAVIN 2013). Potato tubers contain from 1 to 1.2% of minerals, the most important of which are potassium, magnesium, nitrogen and phosphorus (GUGALA et al. 2012). As well as performing important functions in the human body, macro-elements are an integral part of many enzymes and play an important role in the regulation of metabolism (WHITE, BROADLEY 2009b).

Quantities of mineral substances in potato tubers can be highly diverse, both by being cultivar-specific and because they are affected by multiple factors, weather and growing conditions, supply of nutrients, etc. (LESZCZYNSKI 2000, ANDRE et al. 2007, BURGOS et al. 2007).

In this century of progress and innovations, eco-friendly technologies and food quality are increasingly more often taken into consideration (LAIRON 2010). In order to maintain and improve food quality and safety, it is necessary to search for alternative farming methods. Biodynamic agriculture is a type of organic farming (BURKITT et al. 2007), which contributes to sustainable agricultural development (PONZIO et al. 2013) and does not use synthetic chemicals, i.e. pesticides, fertilizers, growth regulators and others (ZALLER, KOPKE 2004). Unlike organic farming, farmers engaged in biodynamic farming use biodynamic preparations (BP), whose main purpose is to promote metabolism of energy and nutrients, and consequently to improve the nutritional properties of plants and soil quality, instead of providing crops with nutrients (RAUPP, KONIG 1996, BACCHUS 2010).

According to scientific research data, foods farmed and processed in biodynamic farms are nutritionally more valuable (JAYASREE, ANNAMMA 2006). However, studies on the impact of BP preparations on the potato tuber quality indicators are very limited. Therefore, the aim of our study has been to evaluate the influence of biodynamic preparations on the content of some mineral elements and starch in tubers of coloured potato cultivars.

MATERIAL AND METHODS

A field experiment was carried out at an organic farm (Prienu district) in 2013-2014. The material consisted of three coloured potato cultivars: Vitelotte (medium late), Blue Congo (medium early with purple flesh) and Red Emmalie (medium early with red flesh). Apart from using BD preparations,

the potatoes were grown according to the traditional potato growing technology. They were planted in May and harvested in September. The field experiment was arranged randomly and carried out in four replications. The overall size of a plot covered by the potato experiment variant was 17.5 m², whereas the size of a plot harvested for sampling was 10 m².

The main soil properties were as follows: soil pH_{KCl} 6.86-6.92, content of total nitrogen 18.51-20.23 mg kg⁻¹, available phosphorus 176.1-181.8 mg kg⁻¹ and available potassium 207.6-248.8 mg kg⁻¹.

A two-factor experiment was performed: I – three potato cultivars (Vitelotte, Blue Congo and Red Emmalie), II – biodynamic (BD) preparations 500 and 501 used for field spraying. There were four treatments to evaluate the efficacy of BD preparations: 1 – control sample (without BD preparations); 2 – BD preparation 500 (the soil was sprayed two weeks before the planting of potatoes, 1% solution); 3 – BD preparation 501 (potato leaves were sprayed twice early in the morning with 0.5% solution in the VIII and IX stages of organogenesis); 4 – a blend of two preparations, BD 500 and BD 501 (two weeks before the planting of potatoes the soil was sprayed with BD preparation 500 with 1% solution and later potato leaves were sprayed twice early in the morning with BD preparation 501 with 0.5% solution in the VIII and IX stages of organogenesis).

BP preparation 500 is made from cow manure. A cow's horn is filled in with manure and buried in soil at a depth of 40-60 cm in late autumn. It is left to be fermented for 6 months in the soil. The resulting product is dissolved in water and sprayed on the soil. BP preparation 501 is made of silicon dioxide. This product is prepared in the same way as preparation 500, but a cow's horn is filled with ground silica powder and buried for 6 months in spring. Product 501 is used to spray plants several times during the plant growing period. BD preparations 500 and 501 were purchased from Demeter, a certified farm in Germany which specializes in production of biodynamic preparations (CvW KG, Internationale Biodynamische Präparatezentrale).

The weather conditions (air temperature, rainfall) during the potato growing seasons 2013-2014 are given in Table 1.

Table 1
Weather conditions during the potato growing seasons in 2013-2014

Years	Months					Mean value
	May	June	July	August	September	
Air temperature (°C)						
2013	16.07	18.52	18.11	17.93	12.35	16.60
2014	13.24	14.57	20.54	17.83	13.12	15.85
Long-term average 1895-2006	12.30	15.60	17.60	16.60	12.20	14.90
Rainfall (mm)						sum
2013	63.80	45.90	118.5	67.20	104.3	399.7
2014	84.20	49.40	52.50	111.3	32.40	329.8
Long-term average 1895-2006	53.80	62.60	81.20	80.30	52.60	330.5

Chemical analyses of potato tubers were conducted in a laboratory of the Food Raw Materials, Agronomical and Zootechnical Research Centre and in a chemical laboratory of the Lithuanian Research Centre of Agriculture and Forestry. Each laboratory sample comprised 5 kg of tubers. Dry matter was determined by drying samples to constant weight at a temperature of 105°C (LST ISO 751:2000); starch was determined by the *polarimetric method*; total nitrogen was assessed by the Kjeldahl method; total phosphorus was measured photometrically after wet digestion in sulphuric acid; total potassium and magnesium were estimated by atomic absorptiometry (using AAnalyst 200).

Soil analyses were conducted at the Laboratory of Food Raw Materials, Agronomic and Zootechnical Research Centre of Aleksandras Stulginskis University. Soil pH_{KCl} was established by the potentiometric method in 1N KCl extract. The content of total nitrogen in the soil was established by the Kjeldahl method. The content of available phosphorus was determined by the CAL method using a spectrophotometer while available potassium was assayed on a flame photometer.

Analyses were performed in triplicates. The experimental data were statistically processed by ANOVA, software Statistica 7.0 (StatSoft, USA). Averages of the research data were calculated and the Fisher LSD test ($p < 0.05$) was applied to estimate statistical significance of differences.

RESULTS AND DISCUSSION

Quality of potatoes is related to their nutritional value. The dry matter content, one of the main indicators of the quality of potato tubers, depends on genetic characteristics of a given cultivar, meteorological conditions, growing technologies, tuber maturity, and can range from 13 to 37% (RAINYS et al. 2005, JARIENĖ et al. 2008, HASSANPANAH et al. 2011). The research data suggest that the BP preparations did not have any significant influence on the dry matter content of potato tubers in any of the variants (Table 2). The largest amount of dry matter in potato tubers was determined when both 500 and 501 BP preparations had been applied, in which case it reached 22.03 %, i.e. 2.51% more dry matter compared to the control variant of tubers, where the preparations had not been used. The smallest percentage of dry matter (21.33%) was found in potato tubers of the variant sprayed with BP preparation 500. The research has shown that the variation of dry matter was significantly influenced by the genetic characteristics of a cultivar, and essential differences in the percentages of dry matter in potato tubers were identified among all the tested cultivars (Table 3). The significantly highest dry matter content (27.03%) was determined in tubers of the late season cultivar Vitelotte, while the significantly lowest one (18.99%) was observed in tubers of the early season cultivar Red Emmalie. These results coincide with literature reports, which claim that the amount of dry matter depends on the

Table 2

The influence of BD preparations 500 and 501 on the chemical composition of potato tuber (means of 2013-2014 and of cultivars)

Chemical composition of potato tubers	Treatment			
	control (without preparation)	preparations 500	preparations 501	preparation 500 in combination with preparation 501
Dry matter (%)	21.49 ^a	21.33 ^a	21.99 ^a	22.03 ^a
Starch (% f.m.)	14.27 ^b	14.28 ^b	14.97 ^a	15.05 ^a
Potassium (g kg ⁻¹ d.m.)	25.03 ^a	26.39 ^a	27.01 ^a	26.40 ^a
Phosphorus (g kg ⁻¹ d.m.)	4.412 ^a	4.610 ^a	4.675 ^a	4.371 ^a
Nitrogen (g kg ⁻¹ d.m.)	14.20 ^a	14.41 ^a	14.58 ^a	14.42 ^a
Magnesium (g kg ⁻¹ d.m.)	1.355 ^a	1.221 ^a	1.260 ^a	1.293 ^a

^{ab} – different letter superscripts in the same row indicate significant differences among samples ($p < 0.05$)

Table 3

The influence of cultivar characteristics on the chemical composition of potato tubers (means of 2013-2014 and of treatments).

Chemical composition of potato tubers	Cultivar		
	Red Emmalie	Blue Congo	Vitelotte
Dry matter (%)	18.99 ^c	20.02 ^b	27.03 ^a
Starch (% f.m.)	12.61 ^c	13.82 ^b	18.17 ^a
Potassium (g kg ⁻¹ d.m.)	29.51 ^a	25.42 ^b	23.63 ^b
Phosphorus (g kg ⁻¹ d.m.)	4.664 ^a	4.671 ^a	4.190 ^b
Nitrogen (g kg ⁻¹ d.m.)	14.72 ^a	14.35 ^a	14.22 ^a
Magnesium (g kg ⁻¹ d.m.)	1.475 ^a	1.172 ^b	1.210 ^b

^{abc} – different letter superscripts in the same row indicate significant differences among samples ($p < 0.05$)

ripening time of a cultivar, being generally larger in potato tubers of late season cultivars (ASAKAVIČIŪTĖ et al. 2007, ZARZYNSKA 2013).

Starch is the basic component of potato tuber, as it constitutes 8-29.5% of the fresh matter. (MUSILOVA et al. 2009). It is stated in literature that the accumulation of starch in potato tubers is determined by the genetic features of a cultivar. Under different growth conditions, its quantity in the same

variety of potato tubers can vary from 7 to 8% (SAWICKA 2003). The analysis of the average research data has revealed that the largest and statistically reliable starch content in the dry matter of potato tuber accumulated when both BP preparations 500 and 501 had been applied. Under the impact of these preparations, the starch content in potato tubers increased by 5.47% compared with the control variant, in which the preparations were not used (Table 2). Also, BP preparation 501 alone substantially increased the amount of starch in potato tubers. Similar results were observed by NORGIA et al (2008). According to their research, different varieties of potato tubers gained 3-12% larger starch content when treated with BP preparations compared with the same cultivars which were grown without the use of BD products. Our results suggest that the genetic traits of a cultivar are crucial for starch accumulation, for instance tubers of cv. Vitelotte potatoes accumulated 44.09% more starch than the minimally starchy potato tubers of cv. Red Emmalie (Table 3). Such findings highlight the existence of potato genotype variability.

Potato tubers are rich in various minerals, including the most important one, such as potassium (FLIS et al. 2012), which encourages plants' macromolecular synthesis of carbohydrates and vitamins, and improves metabolism and water uptake to plant cells. Therefore, potassium is necessary for the synthesis of sugars, including starch, and the production of plentiful, good quality potato tuber yield (JANUŠAUSKAITĖ, ŽĖKAITĖ 2008). Other authors show that the potassium content in potato tubers can vary greatly depending on cultivar-specific genetic traits as well as meteorological and plant growth conditions (REPŠIENĖ, MINEIKIENĖ 2006, WHITE et al. 2009a). The results of our research showed that the BP preparations had no significant effect on potassium in potato tubers compared with the control variant, where the products were not sprayed (Table 2). However, a trend was identified for a higher potassium content in potato tubers treated with the BP preparations. The potassium level in tubers of the tested potato cultivars ranged from 23.63 to 29.51 g kg⁻¹ d.m. (Table 3). The significantly highest amount of potassium was identified in cv. Red Emmalie tubers. The amounts of potassium in tubers of Vitelotte and Blue Congo were similar and not significantly different.

Phosphorus is another important mineral found in potato tubers (NASSAR et al. 2012). It accelerates the development of potato plants, promotes tuber growth and dry matter tuber accumulation (LOCASCIO, RHUE 1990). The use of BP preparations 500 and 501 had no significant effect on the phosphorus content of potato tubers in any of the variants of our experiment (Table 2). The research showed that genetic traits of a cultivar determine the accumulation of phosphorus in tubers. The statistically verified low content of phosphorus was determined in cv. Vitelotte tubers – 4.190 g kg⁻¹ d.m. (Table 3), and the amounts of this element in tubers of Congo Blue and Red Emmalie were similar, respectively 4.671 g kg⁻¹ and 4.664 g kg⁻¹ of dry matter. Other scientists have also confirmed its dependence on characteristics of a cultivar (TEKALIGN, HAMMES 2005, WICHROWSKA et al. 2009). Such

differences in amounts of phosphorus and potassium among cultivars can be explained by differences in their ability to absorb these elements from the soil and to transport the elements from the roots to other parts of plants (TREHAN 2005).

Potatoes are rich in nitrogen, which is a component of amino acids, proteins, nucleic acids, certain vitamins, growth regulators and other substances. According to the mean results of our experiment, the BP preparations had no significant effect on the nitrogen content in potato tubers (Table 2). The nitrogen content in potato tubers ranges from 13 to 17 g kg⁻¹ d.m. (JOERN, VITOSH 1995). It was found that potato tubers of early season cultivars accumulate more nitrogen than late season cultivars (LESZCZYNSKI 2000). Our analysis indicated that the content of nitrogen differed only slightly in the tubers and no essential differences were found between the three cultivars: the early season cultivar Red Emmalie accumulated the most nitrogen (14.72 g kg⁻¹ d.m.), while the least nitrogen was determined in tubers of the late season cultivar Vitelotte (14.21 g kg⁻¹ d.m.) – Table 3.

Potatoes are a good source of magnesium, which is vital for the human body (LUIS et al. 2011). Likewise, this microelement is irreplaceable in plant nutrition as it performs basic physiological functions. Being included in chlorophyll, magnesium is involved in photosynthesis; it also helps to transport phosphorus and sugars in the plant, participates in the synthesis of starch and is active in other physiological and biochemical processes (SHAUL 2002). Our research revealed that the content of magnesium in potato tubers decreased, albeit only slightly, after spraying potatoes with the BP preparations (Table 2). The magnesium content in the tested potato tubers ranged from 1.172 to 1.475 g kg⁻¹ d.m., which agrees with data published by other authors (BETHKE, JANSKY 2008). The tubers of cv. Red Emmalie accumulated a substantially larger amount of magnesium than the tubers of Blue Congo and Vitelotte (Table 3).

CONCLUSIONS

1. The BP preparations had no significant effect on the content of dry matter, potassium, phosphorus, nitrogen and magnesium in potato tubers. The starch content in potato tubers was substantially increased by BP 501 preparation and the use of both preparations 500 and 501 combined during the growth period.

2. The significantly highest amounts of potassium (29.51 g kg⁻¹ d.m.) and magnesium (1.475 g kg⁻¹ d.m.) were accumulated by cv. Red Emmalie tubers. The tubers of cv. Vitelotte accumulated the highest amounts of dry matter (27.03%) and starch (18.17%).

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