JMBFS
Journal of Microbiology, Biotechnology and Food Sciences
International peer-reviewed scientific online journal
Published by Faculty of Biotechnology and Food Sciences

IMPACT OF CONVENTIONAL AND ORGANIC FERTILIZER APPLICATION ON THE CONTENT OF MACRO- AND MICROELEMENTS IN THE FRUIT OF HIGHBUSH BLUEBERRY (*VACCINIUM CORYMBOSUM* L.)

Michal Medvecký[*1], Ján Daniel*[1], Alena Vollmannová[2], Stanislav Zupka[2]*

Address(es): Michal Medvecký,
[1] Plant Production Research Center - Grassland and Mountain Agriculture Research Institute Banská Bystrica, Krivá Research Station, Krivá 62, 027 55, Krivá, Slovakia.
[2] Slovak University of Agriculture, Faculty of Biotechnology and Food Sciences, Department of Chemistry, Tr.A.Hlinku 2, 949 76, Nitra, Slovakia.

*Corresponding author: scpv@orava.sk, alena.vollmannova@uniag.sk

ARTICLE INFO

Received 11. 10. 2013
Revised 21. 11. 2013
Accepted 9. 1. 2014
Published 1. 2. 2014

Regular article

OPEN ACCESS

ABSTRACT

The aim of this study is to provide information on the content of micro- and macroelements in fruits of highbush blueberry (*Vaccinium corymbosum* L.) cultivated using of different fertilizer application in conditions of northern Slovakia. The study was realised in the experimental station Kriva in Orava region. Six cultivars (Bluejay, Nelson, Bluecrop, Patriot, Berkeley and Brigitta) of highbush blueberries (*Vaccinium corymbosum* L.) were studied. Three variants of blueberry cultivation were investigated. The first one was the cultivation with mineral fertilizers application (30 kg N, 10 kg P and 30 kg K.ha $^{-1}$), the second variant was realised with application of Hosticke organic fertilizer and the third (control) variant of blueberry cultivation was realised without any fertilization. The content of macro- and microelements after previous microwave decomposition was in blueberries samples determined by AAS method (AAS Varian AA Spectr DUO 240FS/240Z/UltrAA). In our study the highest content of macroelements (Mg – 104.72 mg.kg^{-1}, P – 156.24 mg.kg^{-1}, Ca – 646.,79 mg.kg^{-1}, Na – 320.32 mg.kg^{-1} and K – 1416.78 mg.kg^{-1}) was determined in cv. Patriot in the control variant without any treatment and the lowest one in cv. Bluecrop in the variant with the mineral fertilization. The highest content of microelements (Fe – 156.60 mg.kg^{-1}, Mn – 8.68 mg.kg^{-1}, Zn – 1.081 mg.kg^{-1}, Cu – 0.507 mg.kg^{-1}) was detected in cv. Nelson in the variant with the mineral fertilization and the lowest one in cv. Bluecrop in the control variant without any treatment.

Keywords: mineral fertilizer, organic fertilizer, macroelements, microelements, highbush blueberry

INTRODUCTION

In Slovakia there are many areas with natural resources of some forest fruit, such as raspberries, blueberries, blackberries, cranberries, etc. These fruits contain vitamins, minerals and polyphenolic compounds and are resistant against unsuitable climatic conditions and can adapt to more severe soil-climatic conditions. Lower acreage of natural (original) vegetation, their low yield and obvious devastation have caused lack of mentioned small fruits on our market.
Slovakia is known by wild blueberries and cranberries collection since past. Part of these minor fruits grow in national parks and protected areas where harvesting is prohibited or restricted because of biodiversity preservation.
High cranberry or higbush blueberry (*Vaccinium corymbosum* L.) originates from Canada, where it grows on very acid, less fertile soils with a higher content of humus substances (**Trevett, 1962**).
According to **Häkkinen et al. (1999)** small forest fruits, both wild or bred, are traditional part of Finnish consumers, with significant content of biological active non-nutrients, but also of essential nutritive components. The essential elements (K, Ca, P, Mg, Al, B, Cu, Fe, Na, Mn and Zn) are important components of highbush blueberries, while suitable fact for human organism is low content of Na (**Bushway et al., 2006**). **Prior et al. (1998)** consider blueberries as one of the richest sources of antioxidant phytonutrients, while composition and content of phenolic compounds in blueberries have changed in relation to variety, period, as well as to locality of growing (**Giovanelli, Burati, 2009; Vinson et al . , 2001; Ruel, Couillard, 2007**).
Cranberries due their nutritional composition rank among the healthiest fruits at the world. They are a rich source of bioactive components, mainly polyphenols with strong antioxidant and antimicrobial effects, which inhibit the growth of pathogenic bacteria such as Escherichia coli, Helicobacter pylori and other pathogens (**Wang, Jiao, 2000; Lin et al., 2005; Vattem et al. , 2005; Borowska et al., 2009**). Berries contain vitamins, minerals, and colorants (anthocyanins), which have an extremely positive effect on the human body. They serve as a support tool for diabetics, increase immunity, improve metabolism, reduce cholesterol level in blood and act bactericidal. They are rich in phenolic acids and flavonoids, which inhibit oxidative processes, mainly oxidation of LDL cholesterol (**Porter et al. 2001; Yan et al., 2002; Ruel, Couillard, 2007; Tumbas et al., 2007**) Anticancer properties of cranberries make them a popular ingredient in dietary prevention of cancer (**Seeram et al., 2006; Neto, 2007; Boraowska et al ., 2009**).
Fertilization plays an important role in high quantity production of cranberries (**Ismail, 1974**). Widespread use of fertilizers is one of the causes of environmental degradation in the form of pollution of soil, water and atmosphere. These problems have resulted in many developed countries to take measures to prevent or minimize the negative effects of excessive and often irrational agricultural production. This fact is reflected in the development and implementation of the principles of intensive integrated pest management and integrated production. Integrated production has to determine a maximum limit of fertilizers on the plant protection (**Hayden, 2001**) .
There have been many reports in literature on fertilization of Vaccinium species (**Gough, 1996; Korcak, 1988**). On the other hand studies of comparisons of organic and conventional fertilization influence on macroelement and microelement content in various food plants are rare, and there has been little published.
The aim of this study is to provide information on the content of micro- and macroelements in fruits of highbush blueberry (*Vaccinium corymbosum* L.) cultivated using of different fertilizer application in conditions of northern Slovakia.

MATERIAL AND METHODS

The experiments were realised in locality of Orava region in northern Slovakia in cadaster of Krivá. The average annual temperature in the area is 6° C and annual rainfall of 900 mm.
Experimental station with blueberry cultivars is located on a slope with an inclination of 10° and north- eastern exposure at an altitude of 634 m .
Six cultivars of highbush blueberries (*Vaccinium corymbosum* L.) were studied (Table 1). Fruit samples for analysis were collected in August 2012.

Three variants of blueberry cultivation were investigated. The first one was cultivation with mineral fertilizers application. The nutrients (30 kg N, 10 kg P and 30 kg K.ha $^{-1}$) were applied in the spring. Nitrogen dose was divided into three parts (1/3 of the total dose in the first half of April, 1/3 at the end of May and 1/3 at the end of June). Phosphorus and potassium were applied once in the spring . The second variant of blueberry cultivation was realised with application of Hosticke organic fertilizer, which was applied in dose 1 kg per 10 m^2 at the beginning of vegetation (in the first half of April) and in dose of 0.8 kg per 10 m^2 during vegetation (in the second decade of June) .
Hosticke organic fertilizer contains fermented cow and horse manure, crushed and granulated horn and natural guano coming from the droppings of seabirds. It is a purely natural product without addition of industrially produced components containing 5% N, 3.5% P_2O_5, 1% K_2O and 0.5% MgO.
The third (control) variant of blueberry cultivation was realised without any fertilization .
The content of macro- and microelements after previous microwave decomposition was in blueberries samples determined by AAS method (AAS Varian AA Spectr DUO 240FS/240Z/UltrAA).

Table 1 Characteristics of observed highbush blueberry (*Vaccinium corymbosum* L.) cultivars

Cultivar	Characteristics
Bluejay	medium early cultivar, bush is weakly to moderately stout, well fertile; fruits are medium-sized and very strong, resistant to cracking, with a wine sweet taste
Nelson	medium late cultivar, bush is upright and strong, suitable for colder areas, very fertile; fruits are very big, light blue and solid and have an excellent quality
Bluecrop	medium early cultivar, bush is upright; fruits are very big, light blue with a full taste
Patriot	medium early cultivar, very fertile, a moderate growth of plant, fruits are large and strong, unbalanced in size
Berkeley	medium late cultivar, bush is sprawling open, fast growing, highly productive, fruits are light blue and large
Brigitta	medium late till late cultivar, bush is upright, very fertile, fruits are medium sized, very firm, light blue, slightly acidic, fruit can be fresh during a very long time storage

RESULTS AND DISCUSSION

Peredo et al. (2009) have determined and compared taxa richness, abundance and diversity of the edaphic mesofauna community between plantations of cranberries (Vaccinium sp.) subjected to organic and conventional management in farms in central-south Chile (37°28'S), as also evaluated changes produced in their diversity and abundance diversity and abundance, as result of the change from conventional to organic management
The content of K in fruits of investigated highbush blueberry is presented in Figure 1. The average K content in control variant without any treatment was 1014 mg.kg^{-1}, followed by variant with the organic fertilization (987 mg.kg^{-1}) and variant with the mineral fertilization (905 mg.kg^{-1}). The highest K content was determined in cv. Patriot in the control variant (1417 mg.kg^{-1}) and the lowest one in cv. Bluecrop in variant with the mineral fertilization (658 mg.kg^{-1}).

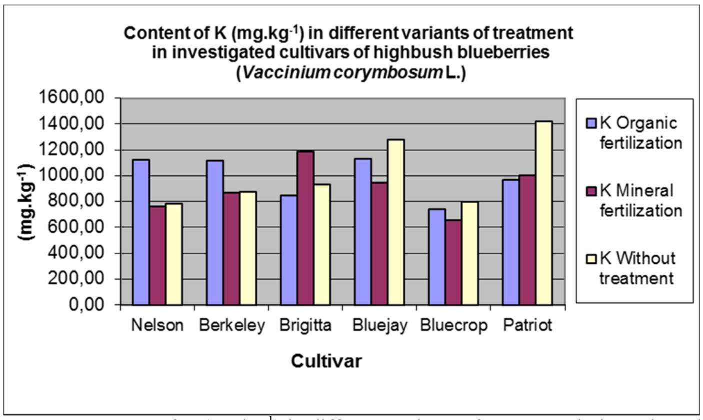

Figure 1 Content of K (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries
(*Vaccinium corymbosum* L.)

A different order was observed in values of Mg content in highbush blueberries (Figure 2). The highest average Mg content was determined in control variant (63 mg.kg^{-1}) and the lowest one in variant with the organic fertilization (54 mg.kg^{-1}). In fruits of blueberries in variant with the mineral fertilization the average Mg content 56 mg.kg^{-1} was detected.

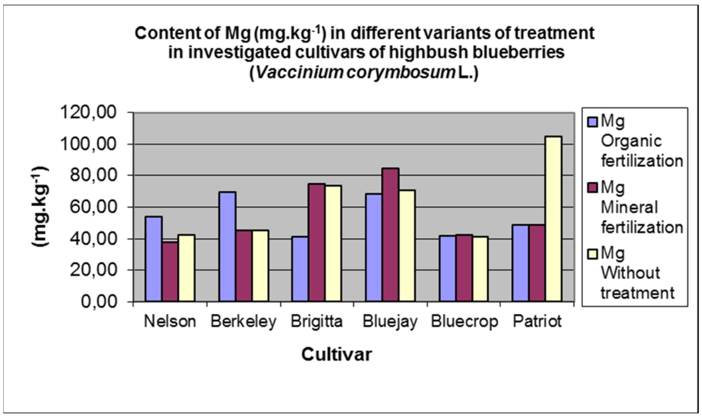

Figure 2 Content of Mg (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries (*Vaccinium corymbosum* L.)

Bieniek et al. (2006) present the results of a 2-year study on the influence of fertilization with urea phosphate on content of macroelements in four cultivars of cranberry fruits. The studies revealed important cultivar-related diversity of the content of mineral components. A higher content N, P and K in dry matter was obtained after applying higher doses of fertilizers. In Figure 3 the determined values of P content in fruits of investigated highbush blueberry cultivars are presented. The highest average P content was determined in the variant with the organic fertilization (126 mg.kg^{-1}), followed by the control variant without any treatment (116 mg.kg^{-1}) and the variant with the mineral fertilization (112 mg.kg^{-1}).

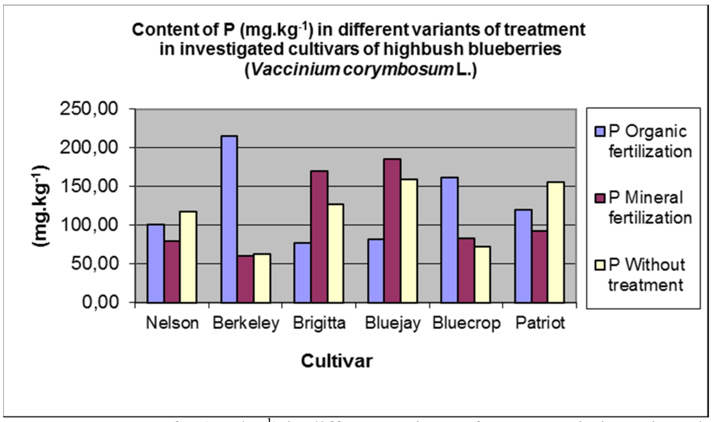

Figure 3 Content of P (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries
(*Vaccinium corymbosum* L.)

Based on the determined average values of Ca content (Figure 4) followed order of investigated variants of treatment can be created: control variant (326 mg.kg^{-1}) > variant with the mineral fertilization (259 mg.kg^{-1}) > variant with the organic fertilization (228 mg.kg^{-1}).

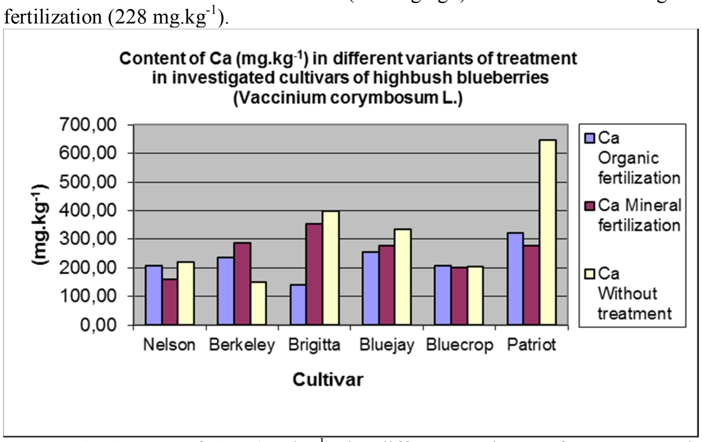

Figure 4 Content of Ca (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries
(*Vaccinium corymbosum* L.)

In fruits of highbush blueberries in the control variant without any treatment also the highest average Na content (306 mg.kg^{-1}) was determined (Figure 5). In the variant with the organic fertilization was a lower Na content detected (254 mg.kg^{-}

$^{-1}$) and the lowest average value of Na content was confirmed in blueberry fruits in the variant with the mineral fertilization (176 mg.kg^{-1})

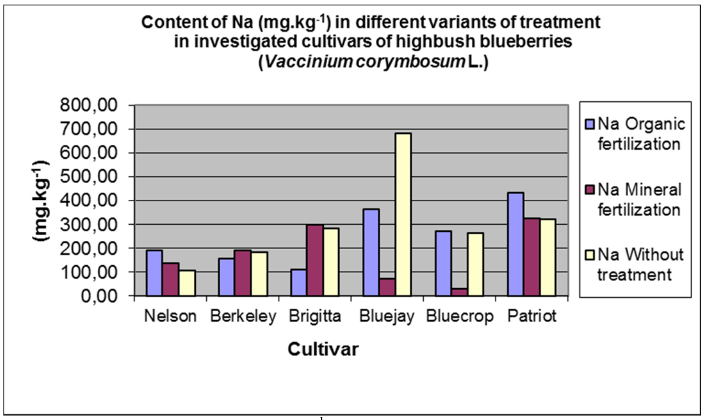

Figure 5 Content of Na (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries (*Vaccinium corymbosum* L.)

The highest average value of Fe content (Figure 6) was determined in fruits of highbush blueberries in the variant with the mineral fertilization (74 mg.kg^{-1}), followed by the control variant without any treatment (34 mg.kg^{-1}) and the variant with the organic fertilization (17 mg.kg^{-1}).

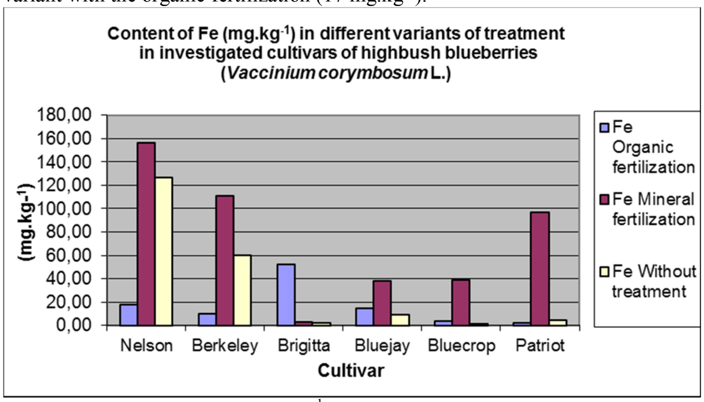

Figure 6 Content of Fe (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries (*Vaccinium corymbosum* L.)

The values of Mn content determined in fruits of investigated cultivars of highbush blueberries are presented in Figure 7. The highest average Mn content was determined in blueberry fruits in the variant with the mineral fertilization (8.3 mg.kg^{-1}), the lowest one in the control variant without any treatment (6.1 mg.kg^{-1}). In the variant with the organic fertilization the average value 6.7 mg Mn.kg^{-1} in fruits of highbush blueberries was determined.

Davenport and Provost (1994) investigated five different cranberry cultivars fertilized with three different N doses. Across all cultivars, tissue N, P, and K levels increased with increasing N dose, whereas Fe tended to decrease with increasing N dose. Only the element Mn showed no relationship to N dose for any cultivar. This research suggests that tissue nutrient concentration may be useful in predicting rot and fruit size potential in cranberries.

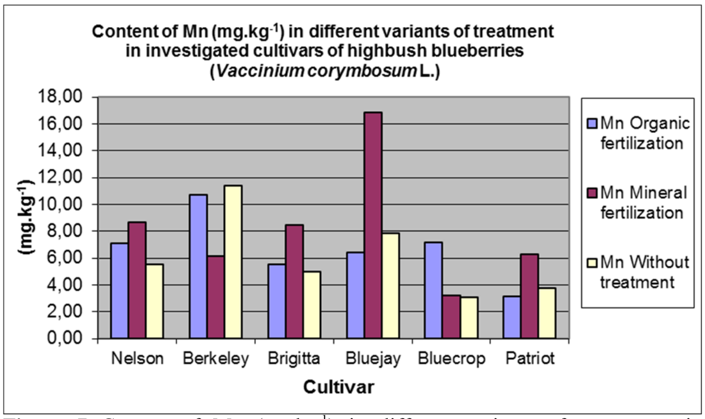

Figure 7 Content of Mn (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries (*Vaccinium corymbosum* L.)

In Figure 8 the determined values of Zn content in fruits of investigated blueberry cultivars are presented. Based on the obtained results the followed order of Zn content in blueberry fruits in the variants of our experiment can be created: variant with the mineral fertilization (1.01 mg.kg^{-1}) > control variant without any treatment (0.75 mg.kg^{-1}) ≅ variant with the organic fertilization (0.74 mg.kg^{-1}).

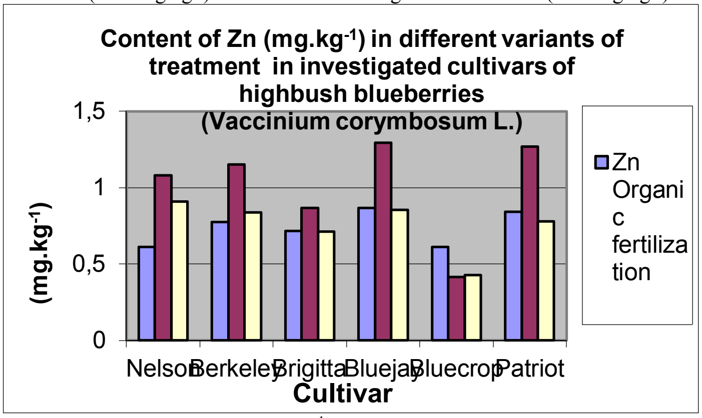

Figure 8 Content of Zn (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries (*Vaccinium corymbosum* L.)

Determined values of Cu content in fruits of highbush blueberries are presented in Figure 9. The highest average Cu content was measured in blueberry fruits in the variant with the mineral fertilization (0.51 mg.kg^{-1}). In the control variant without any treatment and in the variant with the organic fertilization similar average values of Cu content were determined (0.48 mg.kg^{-1} and 0.47 mg.kg^{-1} respectively).

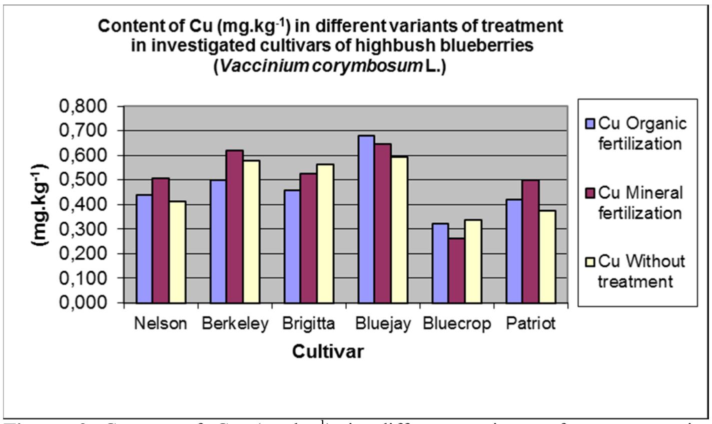

Figure 9 Content of Cu (mg.kg^{-1}) in different variants of treatment in investigated cultivars of highbush blueberries (*Vaccinium corymbosum* L.)

Ancu et al. (2011) investigated influence of three planting substrates on chemical composition of highbush blueberry leaves and fruits. The determined contents of P and K in fruits of blueberries were 95.2 – 150 mg.kg^{-1} and 920 – 1370 mg.kg^{-1} respectively. These values are in agreement with our results.

Close correlation between soil and plant P supply levels was found for American cranberry in Latvia (**Osvalde and Karlsons, 2005**).

On the other hand **Jovančević et al. (2009)** determined significantly higher amounts of Fe, Mn, Zn and Cu in fruits of highbush blueberries.

Generally, in the literature there is little knowledge about the content of macro- and microelements in different highbush cultivars and its changes due the fertilizer application.

CONCLUSION

Nutrition, as one of the major external factors influencing the human organism, is the basis for healthy growth and development of human population. Optimal intake and the composition of food with intake of specific components, e.g. antioxidants, fibre, etc. affect also many lifestyle diseases. Causes of their spread are complex, but changes in nutrition habits and in lifestyle can play very positive role in prevention of their arising. In works of many researchers positive correlation between consumption of fruit, vegetable and products from pseudocereals and prevention of many lifestyle diseases, such as atherosclerosis, oncological diseases, diabetes and arthritis was confirmed. Regular intake of phytochemicals present in these plant foodstuffs can contribute also to slow down the process of aging.

In consistency with world trend 'foodstuffs for future' - foodstuffs with health benefits are preferred in many countries while their position in system foodstuffs and protection of health is very important. Fruits of blueberries are an excellent source macro- and microelements as well as very important bioactive compounds with the antioxidant potential. Blueberries as well as cranberries are often called 'edible superstars' thanks to their significant beneficial impact on the human health. In our study the highest content of macroelements (Mg – 104.72 $mg.kg^{-1}$, P – 156.24 $mg.kg^{-1}$, Ca – 646.,79 $mg.kg^{-1}$, Na – 320.32 $mg.kg^{-1}$ and K – 1416.78 $mg.kg^{-1}$) was determined in cv. Patriot in the control variant without any treatment and the lowest one in cv. Bluecrop in the variant with the mineral fertilization. The highest content of microelements (Fe – 156.60 $mg.kg^{-1}$, Mn – 8.68 $mg.kg^{-1}$, Zn – 1.081 $mg.kg^{-1}$, Cu – 0.507 $mg.kg^{-1}$) was detected in cv. Nelson in the variant with the mineral fertilization and the lowest one in cv. Bluecrop in the control variant without any treatment. In addition to these elements, it is also necessary to monitor the content of risky metals in blueberry fruits because of food safety control.

Acknowledgments: The research leading to these results has received funding from the European Community under project No. 26220220180: Building Research Centre „AgroBioTech".

REFERENCES

ANCU, I., NICOLAE, S., NICOLA,C., MLADIN, P., ANCU, S. 2011. The essential chemical composition of leaves and fruits to highbush blueberry growth on three planting substrates. Scientific papers, R.I.F.G. Pitesti, XXVII, 2011.

BIENIEK, A., BENEDYCKA, Z., KRZEBIETKE, S. 2006. Effect of different N, P, K, S fertilization on contents of macroelements in cranberry fruits. *Acta Agrophysica,* 7, 821 – 827.

BOROWSKA, E. J., MAZUR, B., KOPCIUCH, R. G., BUSZEWSKI, B. 2009. Polyphenol, anthocyanin and resveratrol massfractions and antioxidant properties of cranberry cultivars. *Food Technology and Biotechnology,* 47, 56-61.

BUSHWAY, R. J. et al. 2006. Mineral and vitamin kontent of lowbusch blueberries. *Journal of Food Science,* 48(6), 1878 – 1878.

DAVENPORT, J. R., PROVOST, J. 1994. Cranberry tissue nutrient levels as impacted by three levels of nitrogen fertilizer and their relationship to fruit yield and quality. *Journal of Plant Nutrition*, 17, 1625 – 1634.

GIOVANELLI G., BURATTI S. 2009. Comparison of polyphenolic composition and antioxidant activity of wild Italian bluberries and some cultivated varieties. *Food Chemistry*, 112, 903-908.

GOUGH, R. E. 1996. Blueberries – North and South. *Journal of Small Fruit & Viticulture,* 4, 106–152.

HÄKKINEN, S., HEINONEN M., KÄRENLAMPI S., MYKKÄNEN H., RUUSKANEN J., TÖRRÖ R. 1999. Screening of seleceted flavonoids and phenolic acids in 19 berries. *Food Research International*, 32, 345 – 353.

HAYDEN, R. A. 2001. Fertilizing blueberries. Purdue University Cooperative Extension Service. *Department of Horticulture*.

ISMAIL, A. A. 1974. Preharvest application of ethephon and SADH on ripening and quality of lowbush blueberry fruit. *HortScience* 9, 205-206.

JOVANČEVIĆ, M., BALIJAGIĆ, J., ANTIĆ-MLADENOVIĆ, S. 2009. Content of essential microelements in raspberry and blueberry fruits grown on different soils from north Montenegro. *Soil and Plant*, 58(3), 147-158.

KORCAK, R. F. 1988. Nutrition of blueberry and other calcifuges. *Horticultural Reviews*, 10, 183–227.

LIN, Y. T., KWON, Y. I., LABBE, R. G., SHETTY, K. 2005. Inhibition of *Helicobacter pylori* and associate durease by oregano and cranberry phytochemical synergies. *Applied and Environmental Microbiology,* 71, 8558-8564.

NETO, C. C. 2007. Cranberry and its phytochemicals: A review of *in vitro* anticancer studies. *Journal of Nutrition,* 137(1), 186-193.

OSVALDE, A., KARLSONS, A. 2005. Nutrient status of the American cranberries, *Vaccinium macrocarpon* Ait.. *Latvian Journal of Agronomy*, 8, 321 – 325.

PEREDO, S. F. P., PARADA, E. Z., VEGA M. C., BARRERA, C. P. S. 2009. Edaphic mesofauna community structure in organic and conventional management of cranberry *(Vaccinium* sp.) plantations: and agroecological approach. *Journal of Soil Science and Plant Nutrition*, 9, 236 – 244.

PORTER, M. L., KRUEGER, C. G., WIEBE, D. A., CUNNINGHAM, D. G., REED, J. D. 2001. Cranberry proantocyanidins associate with low-density lipoprotein and inhibit *in vitro* Cu^{2+}-induced oxidation. In *Journal of the Science of Food and Agriculture,* 81, 1306-1313.

PRIOR R. L., LAZARUS S. A., CAO G., MUCCITELLI H., HAMMERSTONE J.F. 1998. Antioxidant capacity as influenced by total phenolic and anthocyanin content, maturity and variety of Vaccinium species. *Journal of Agricultural and Food Chemistry*, 46, 2686 – 2693.

RUEL, G., COUILLARD, CH. 2007. Evidences of the cardioprotective potencial of fruits: The case of cranberries. *Molecular Nutrition and Food Research*, 51, 692-701.

SEERAM, N. S., ADAMS, L. S., ZHANG, Y., LEE, R., SAND, D., SHEULLER, H. S., HEBER, D. 2006. Blackberry, black raspberry, blueberry, cranberry, red raspberry, and strawberry extracts inhibit growth and stimulate apoptosis of human cancer cells *in vitro*. *Journal of Agricultural and Food Chemistry,* 54, 9329-9339.

TUMBAS, V. T., DILAS, S. M., ČANADANOVIĆ-BRUNET, J. M., CETKOVIC, G. S., SAVATOVIC, S. M. 2007. Solid-phase extraction of antioxidant compounds from commercial cranberry extract and its antiradical activity. *Acta Periodica Technologica,* 37, 157-164.

VATTEM, D. A., GHAEDIAN, R., SHETTY, K. 2005. Enhancing health benefits of berries through phenolic antioxidant enrichment: Focus on cranberry. *Asia Pacific Journal of Clinical Nutrition,* 14, 120-130.

VINSON, J. A., SU, X., ZUBIK, L., BOSE, P. 2001. Phenol antioxidant quantity and quality in foods: Fruits. *Journal of Agricultural and Food Chemistry,* 49, 5315-5321.

WANG, S. Y., JIAO, H. 2000. Scavenging capacity of berry crops on superoxide radicals, hydrogen peroxide, hydroxyl radicals and singlet oxygen. *Journal of Agricultural and Food Chemistry,* 48, 5677-5684.

YAN, X., MURPHY, B. T., HAMMOND, G. B., VINSON, J. A., NETO, C. C. 2002. Antioxidant activities and antitumor screening of extracts from cranberry fruit (*Vaccinium macrocarpon*). *Journal of Agricultural and Food Chemistry,* 50, 5844-5849.